Free Flight Program

Performance Metrics Results to Date

December 2002 Report

INTRODUCTION

The Free Flight Program (FFP) metrics team was established at the beginning of Free Flight Phase 1 with the goal of evaluating the user benefits of Free Flight deployments. The approach used to measuring operational impacts was developed in collaboration with the RTCA Free Flight Steering Committee. This 6th semi-annual Performance Metrics Report continues to focus on performance enhancements associated with the deployments of the User Request Evaluation Tool (URET) and Traffic Management Advisor (TMA). We have also included a summary of two recent studies under Collaborative Decision Making (CDM).

The primary FFP performance goals are to increase capacity (airport and airspace) and improve efficiency (flight times and fuel consumption), while maintaining the current high level of safety. Many of the metrics used in this report can be normalized and translated into delay savings, which is a commonly used measure for improvement value. The intent is for these metrics analyses to quantify user benefits of early system deployments and to be used in the development of benefit/cost estimates for future deployments.

An integral part of the metrics analysis involves in-depth discussions with the air traffic controllers using the FFP tools. These discussions often focus the analyses on specific conditions where improvements are expected. For example, at LAX the controllers at both the TRACON and Los Angeles Center found TMA most useful under Instrument Meteorological Conditions. The complexity of the ATC system drives unexplained variability in data sets making it very important to both collect data on conditions and focus analytical efforts where FFP tools are really being used.

The FFP metrics team includes research analysts, database specialists, and air traffic controllers from the following organizations: the FAA, The CNA Corporation, MITRE CAASD, Analytics Associates, and NEXTOR. Other contractors contribute analyses on an as needed basis.

If you have questions or comments on this document or the FFP metrics program please contact Dave Knorr at 202-220-3357 or Ed Meyer at 202-220-3407.

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1.0 SAFETY

The Free Flight safety metrics have been detailed in previous metrics reports. Each Operational Error (OE) and Operational Deviation (OD) Report at a Free Flight site has been reviewed to see if any FFP tools were identified as a contributing factor. As of December 1, 2002, no FFP capability had been identified as a causal factor in any of these reports. In addition, there have been no references to FFP capabilities in any accident or incident in the National Transportation Safety Board (NTSB) Accident/Incident Data System, in the NTSB Safety Recommendations or the FAA responses to them, in the FAA Accident/Incident Data System (AIDS), or the FAA Near Mid-Air Collision System (NMACS) as of December 1, 2002. However, there have been three reports mentioning FFP capabilities in the NASA Aviation Safety Reporting System (ASRS) since January 1998. The first referenced the Center-TRACON Automation System (CTAS) and the other two, URET.

1.1 Analysis

Analysis of OE/OD trends at Air Route Traffic Control Centers (ARTCCs) and other facilities nationwide show no adverse safety trends that can be associated with the use of Free Flight tools. The references to CTAS and URET in the three ASRS reports mentioned above were not judged to be significant and were not repeated in any other sources.

1.2 Next Steps

As the fielding of Free Flight capabilities proceeds, the FAA will take the following steps to evaluate any safety impacts:

- Continue the analysis of OE and OD rates and severities at current and planned Free Flight sites,
- Continue the comparison between OE and OD rates and severities at Free Flight sites with those found at sites not hosting Free Flight capabilities,
- In coordination with FAA AAT-20, continue to expand the capability to analyze individual OE reports, identifying factors that may be common across multiple OEs, and
- Continue to track available safety reporting systems to identify any references to Free Flight tools as factors in OEs/ODs, incidents, or unsafe situations.

2.0 USER REQUEST EVALUATION TOOL (URET)

URET continues to produce user benefits at the Indianapolis (ZID), Memphis (ZME), Kansas City (ZKC), Cleveland (ZOB), Chicago (ZAU), and Washington (ZDC) ARTCCs, through increased direct routings and reductions in static altitude restrictions. This section updates previous reports with usage statistics and distance savings from these facilities.

The production version of URET, known as the Core Capability Limited Deployment (CCLD), was deployed to six FFP1 Centers between December 2001 and April 2002. ZKC began using the system in December 2001. ZID and ZME switched from prototype to CCLD operation, and ZOB initiated use, in January 2002. In February 2002 URET became available to ZAU controllers, and Washington (ZDC) Center started using the system in April.[1] Our data shows that user benefits seen at the prototype sites (ZID and ZME) are also being enjoyed with CCLD.

2.1 Description

The key URET capabilities for FFP1 include:

- Trajectory modeling,
- Aircraft and airspace conflict detection,
- Trial Planning to support conflict resolution of user or controller requests, and
- Electronic flight data management.

URET processes real-time flight plan and track data from the Host computer system. These data are combined with local airspace definitions, aircraft performance characteristics, and winds and temperatures from the National Weather Service to build four-dimensional flight trajectories for all flights within or inbound to the facility's airspace. URET also provides a "reconformance" function that continuously adapts each trajectory to the observed position, speed, climb rate, and descent rate of the modeled flight.

URET maintains "current plan" trajectories (i.e., those that represent the current set of flight plans in the system) and uses them to continuously check for aircraft and airspace conflicts. When a conflict is detected, URET determines which sector to notify and displays an alert to that sector up to 20 minutes in advance. Trial planning allows a controller to check a desired flight plan amendment for potential conflicts before a clearance is issued. The controller can then send the trial plan to the Host as a flight plan amendment. Neighboring URET systems will exchange flight data, position, reconformance data, and status information in order to more accurately model trajectories.

These capabilities are packaged behind a Computer Human Interface (CHI) that includes both textual and graphical information. The text-based Aircraft List helps the controller manage flight data electronically, reducing the dependence on paper flight strips. The Plans Display manages the presentation of current plans, trial plans, and conflict probe

[1] Two-way Host communication was enabled for the prototype sites ZID and ZME in July 1999.

results for each sector. The Graphic Plan Display (GPD) provides a graphical capability to view aircraft routes and altitudes, predicted conflicts, and trial plan results. In addition, the point-and-click interface enables quick entry and evaluation of trial plan routes, altitudes, or speed changes, and enables the controller to send flight plan amendments to the Host. For more details about URET capabilities, benefits, and the operational concept, please refer to [1].

2.2 Operational Use

As in previous Free Flight benefits reports, we gauge URET use by the number of flight plan amendments entered through the tool. Data obtained directly from the Host and the URET prototype at ZID and ZME allowed measurement of the number of direct amendments and the distance saved because of URET initiated amendments. Direct routes are those that decrease distance, measured from the point of the amendment to the destination airport.

Figure 2-1 shows the total number of direct amendments and the number of URET-initiated direct amendments at ZID from May 1999 through August 2002 using MITRE's prototype. This figure demonstrates that there was a significant increase in flight plan amendments resulting in direct routings since July 1999, when the URET capability was extended to allow amendments to be sent directly to the Host. Similar results were found at ZME using the prototype. Note that MITRE's ability to count URET-initiated direct amendments ended with the installation of CCLD in January 2002. Likewise, MITRE's ability to count the total number of directs at ZME ended in March 2002 and in August 2002 at ZID.

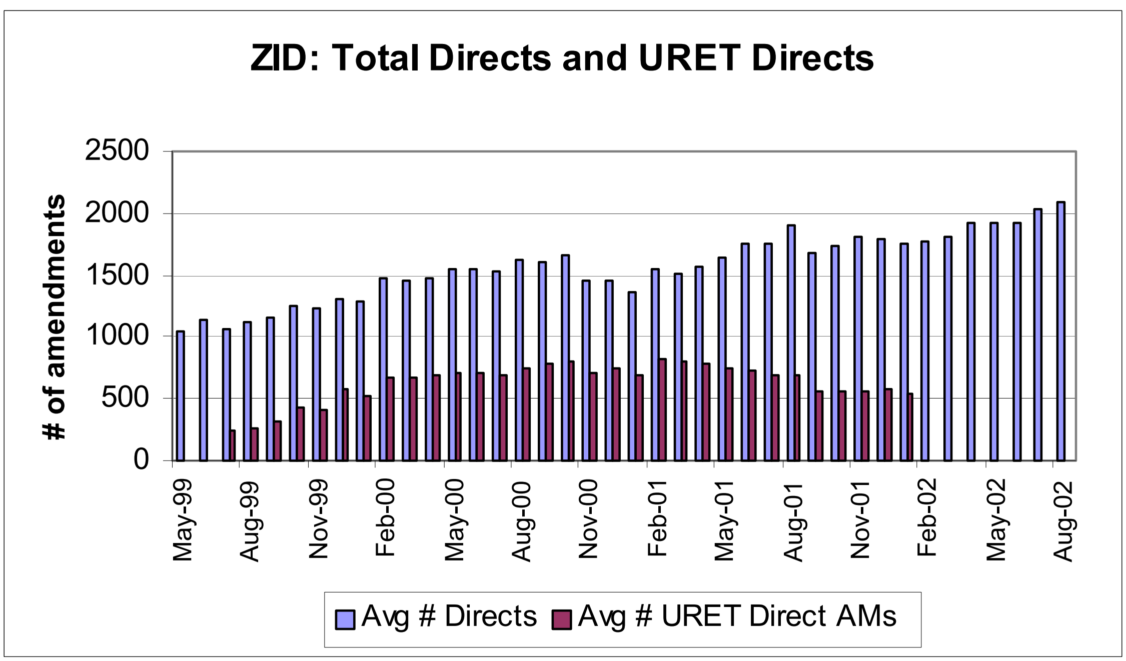


Figure 2-1. URET Directs as a Subset of Total Directs: ZID

In August 2002, the production URET software (CCLD) was upgraded so that all sites could provide this type of flight plan amendment information. Figures 2-2 through 2-7 show the total number of direct amendments and the number of URET-initiated direct amendments for August through November 2002 at ZID, ZME, ZKC, ZOB, ZAU, and ZDC, respectively. Although there is currently insufficient data to show an increase in the number of amendments at the non-prototype CCLD sites (ZOB,ZKC,ZAU, and ZDC), the prototype sites (ZID and ZME) saw no appreciable reduction in amendments with the deployment of CCLD (that is, relative to the prototype system).

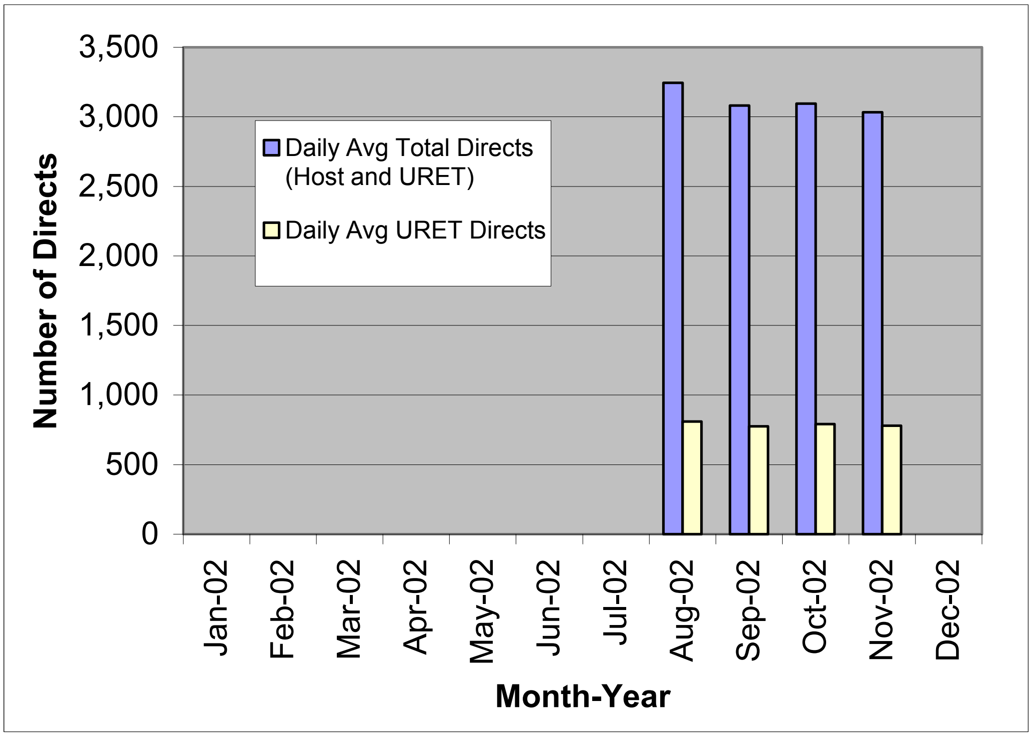


Figure 2-2. URET Directs as a Subset of Total Directs: ZID

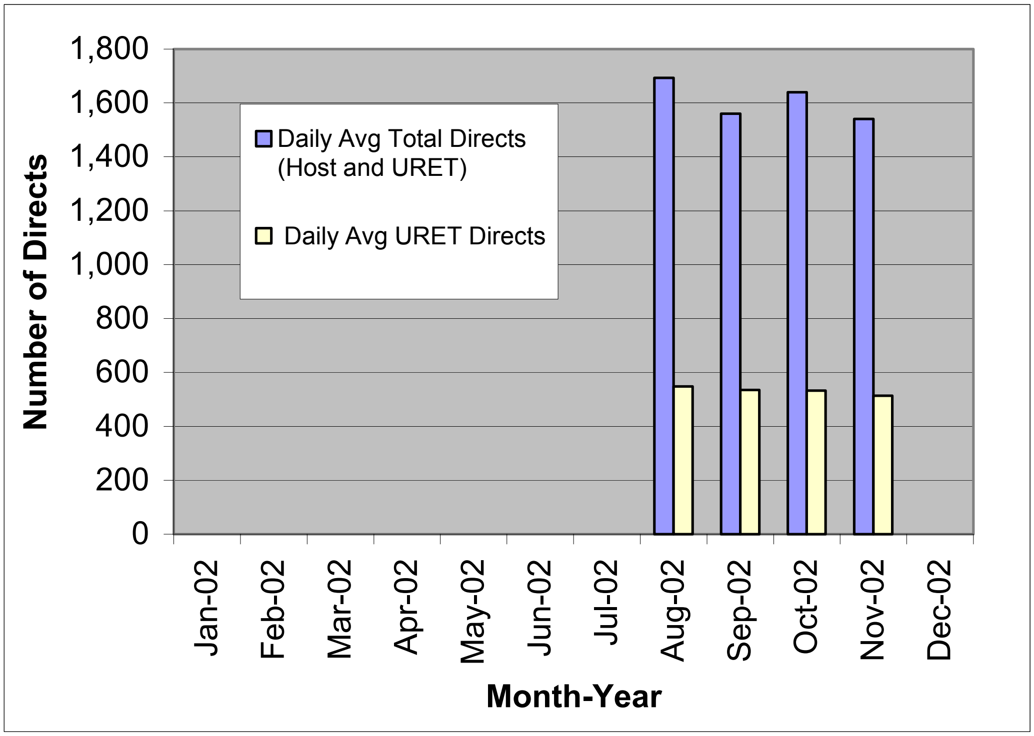


Figure 2-3. URET Directs as a Subset of Total Directs: ZME

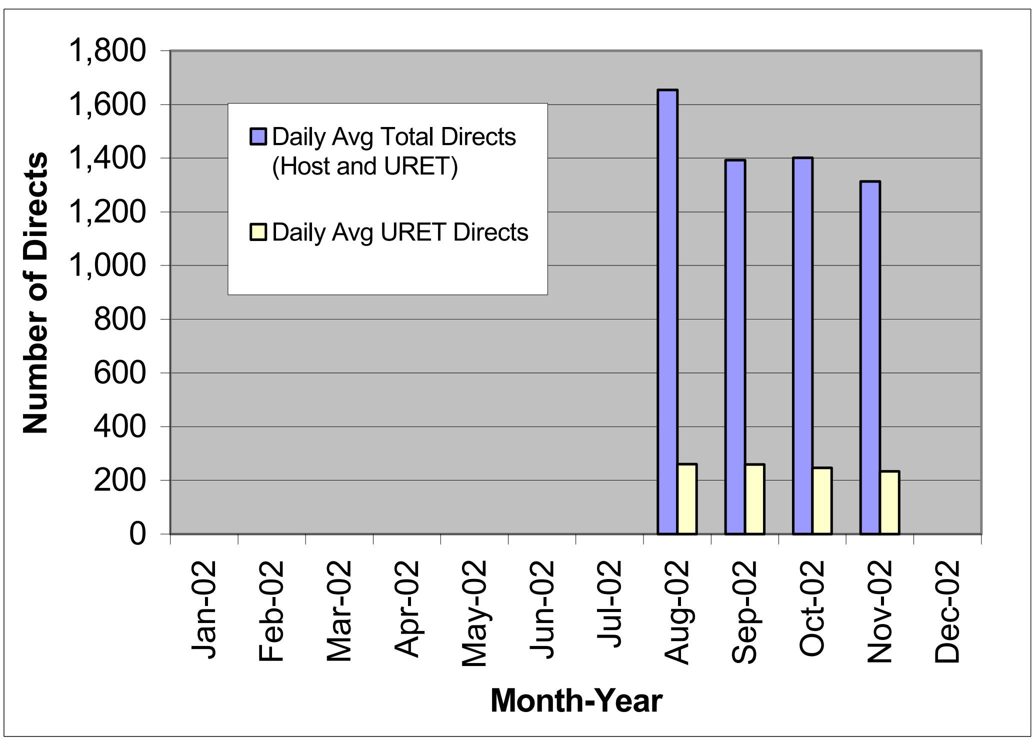


Figure 2-4. URET Directs as a Subset of Total Directs: ZKC

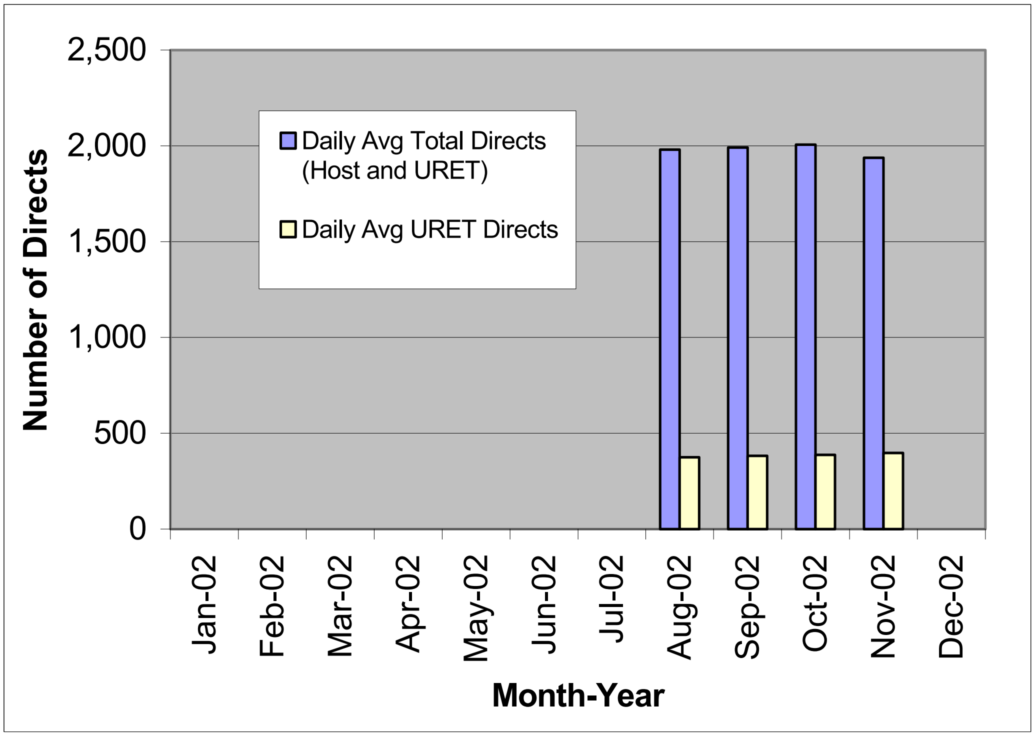


Figure 2-5. URET Directs as a Subset of Total Directs: ZOB

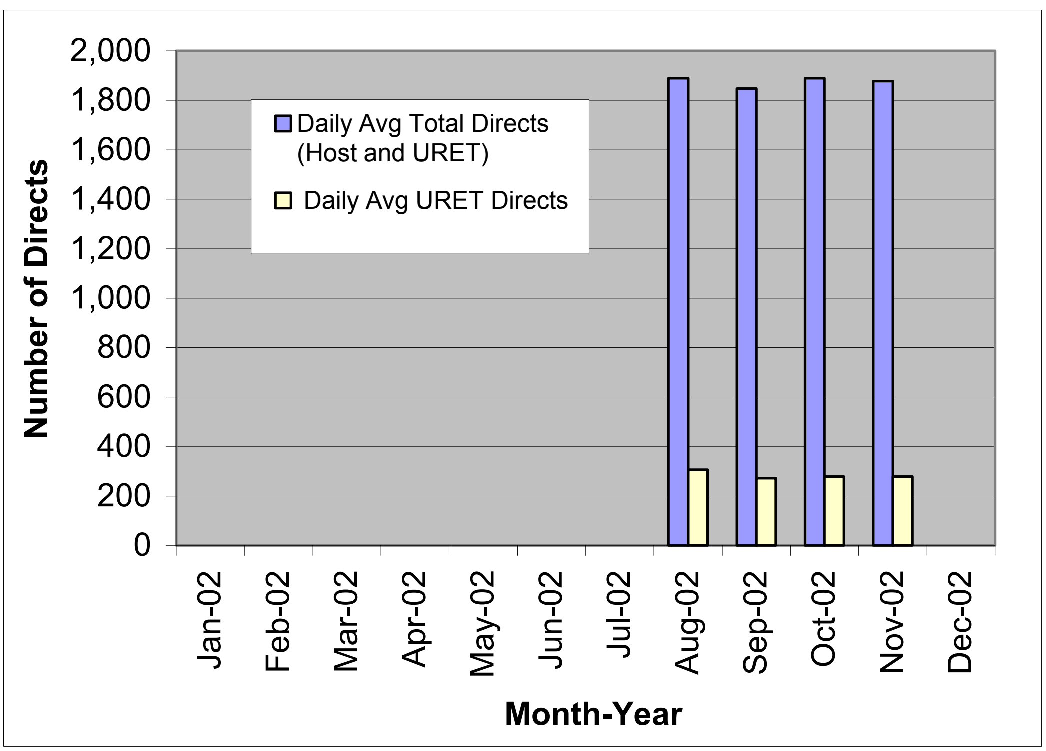


Figure 2-6. URET Directs as a Subset of Total Directs: ZAU

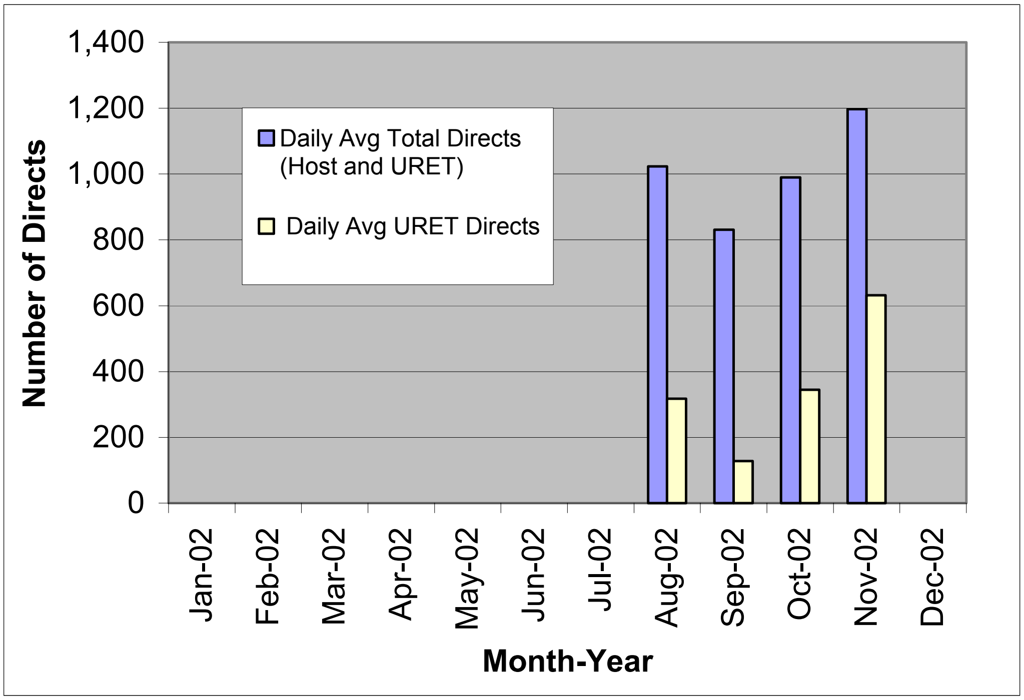
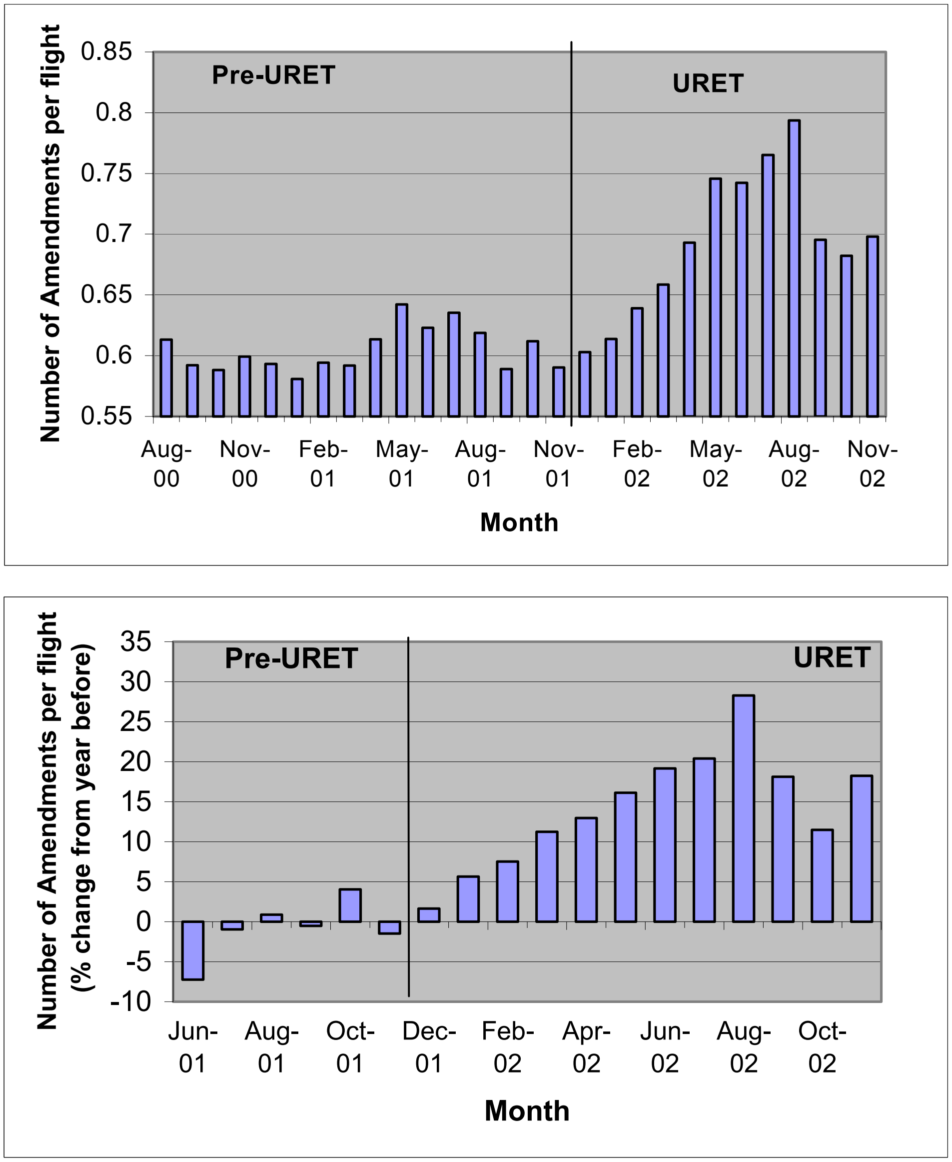


Figure 2-7. URET Directs as a Subset of Total Directs: ZDC

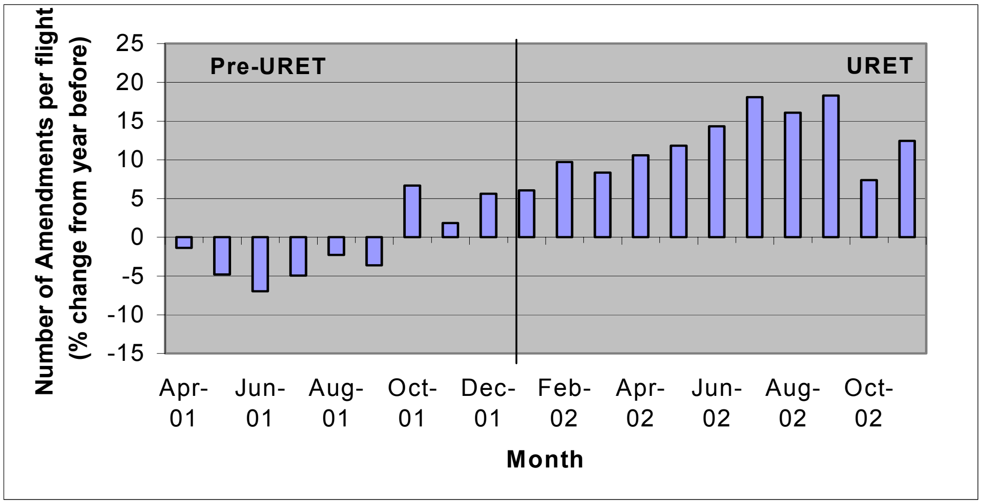
In order to determine whether there was an increase in the number of direct amendments with the deployment of CCLD at the non-prototype sites, we used ETMS data to calculate the total number of flight plan amendments in each Center. If URET were to increase the number of direct amendments (as it did at ZME and ZID), this should be reflected in the total number of amendments per flight within a Center. The top panel of Figure 2-8 shows the monthly average of the number of amendments per flight at ZKC between August 2000 and November 2002. The vertical line in this figure designates the approximate date when URET achieved Initial Daily Use (IDU) at ZKC. To the left of the line, aside from a seasonal effect, there is no obvious trend in the data. In order to account for the seasonal effect, we examine the percentage change from the year before in the number of amendments per flight in the bottom panel of Figure 2-8. In this figure we see an increase in the number of amendments per flight after the introduction of URET at ZKC.

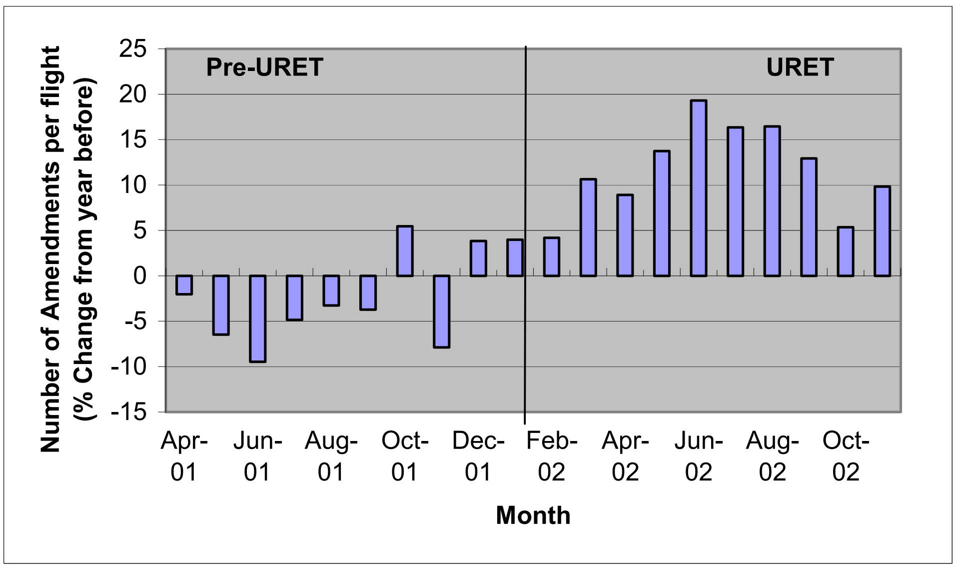


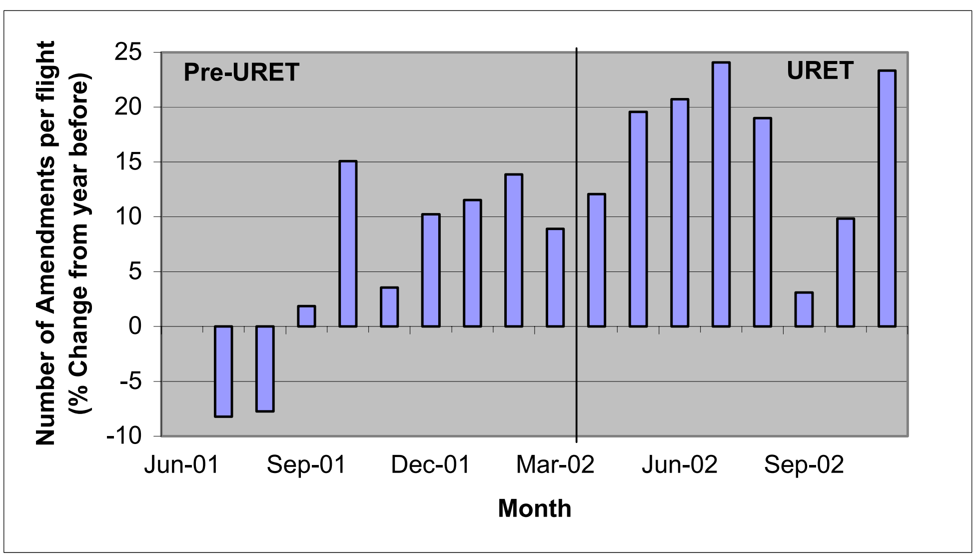
Top: Monthly average of number of amendments per flight. Bottom: Percentage change from year before in the monthly average of number of amendments per flight.

Figure 2-8. Flight Plan Amendments as a Measure of URET Usage at ZKC

Figure 2-9 displays the percentage change in the number of flight plan amendments per flight for the Cleveland, Chicago, and Washington centers. These locations also show a large increase in the number of amendments per flight after the introduction of URET.







Monthly percentage change in average number of amendments per flight at ZOB (Top), ZAU (Middle), and ZDC (Bottom).

Figure 2-9. Flight Plan Amendments as a Measure of URET Usage at ZOB, ZAU and ZDC

2.3 URET User Benefits

2.3.1 Metrics Used

The primary metrics that we use to estimate URET benefits to NAS users are distance/time saved, static altitude restrictions lifted, and increased airspace capacity. A more complete description of the distance and altitude restriction metrics may be found in the FFP1 June 2001 report.[2]

Several measures were employed to estimate the distance savings facilitated by URET. These measures include:

- Change in distance flown because of lateral amendments
- Change in average distance flown through each Center's airspace
- Change in distance flown for specific city pairs
- Change in time of flight for specific city pairs.

In addition to distance and time savings, there have been improvements in fuel efficiency resulting from the removal of altitude restrictions. The ZID and ZME Procedure and Benefits team was established to evaluate and modify or remove altitude restrictions. Once URET is deployed to all bordering Centers, ZID should have increased opportunity to eliminate inter-facility restrictions.

2.3.2 Summary of Previous Results

The primary measure used for the reduction in distance flown is based on data captured directly from URET. We examined all lateral flight plan amendments entered into the Host, and computed the distance savings for each. In the June 2002 metrics report [3], we reported an average distance savings over the baseline of approximately 5000 nmi per Center (the baseline is defined as prior to the URET two-way Host interface). An update to this analysis is included in the next section.

Previous reports also describe three other metrics (*Excess Distance in Center, En Route Distance*, and *En Route Time*), which support the results derived from the analysis of lateral amendments. Excess distance is defined as the excess of actual distance flown over the great circle distance between Center entry and exit points. For simplicity, we assumed that the great circle route was the most efficient route of the flight. The excess distance at ZID and ZME was compared to that at other non-URET Centers from January 2000 through August 2001. We also calculated the en route distance between selected city pairs for flights traversing ZID and ZME airspace over a two-year period (May 1999 to August 2001). The trend in the en route distance indicated a slight decrease in distance between these city pairs, but the slopes of these trends was not statistically significant. For details on the methods used to calculate these metrics see the June 2001 metrics report [3]. For graphs of the final results mentioned above, see the December 2001 report for the distance measures [4] and the June 2002 report for the *En Route Time* measure [3].

The Procedure and Benefits teams at ZID and ZME were established to evaluate static altitude restrictions for modification or removal. Both Centers clearly indicated that they were unwilling to consider lifting restrictions with non-URET centers. The team at ZID identified candidate restrictions for evaluation, tested the restrictions by lifting or modifying them for a period of time to determine feasibility, and determined that approximately twenty of them could be permanently modified or removed. By removing restrictions at sector boundaries, aircraft can fly longer at higher (more fuel efficient) altitudes. The June 2000 metrics report [5] describes the methodology used to determine fuel burn savings for the removed restrictions. Fuel savings were calculated based on aircraft type and nominal fuel burn at different altitudes. This analysis yielded an annual fuel savings at ZID of approximately one million gallons. We expect that this savings will increase with increased removal of restrictions and cooperation between URET-equipped Centers.

2.3.3 Lateral Amendments

Lateral flight plan amendments are defined as those that change the direction of an aircraft but not necessarily its altitude. They include increases (e.g., turns to avoid congestion or heavy weather areas) as well as decreases in distance. The distance saved metric captures the average of the daily sum of distance changes resulting from lateral amendments. Distance saved is computed from the point of the amendment to the destination airport. The data include *all* lateral amendments entered into the Host for the specified time, not just URET amendments.

Figure 2-10 presents the total distance savings from lateral amendments for ZID (as monitored by the prototype) by month through October 2002. Distance savings from lateral amendments have increased from approximately 500 nmi daily (May and June 1999, before URET could send amendments to the Host) to more than 7,000 nmi through Fall 2002. Note that this metric should increase in the post-September 11th era, since, with fewer aircraft flying, there should be less congestion and consequently more direct routings.

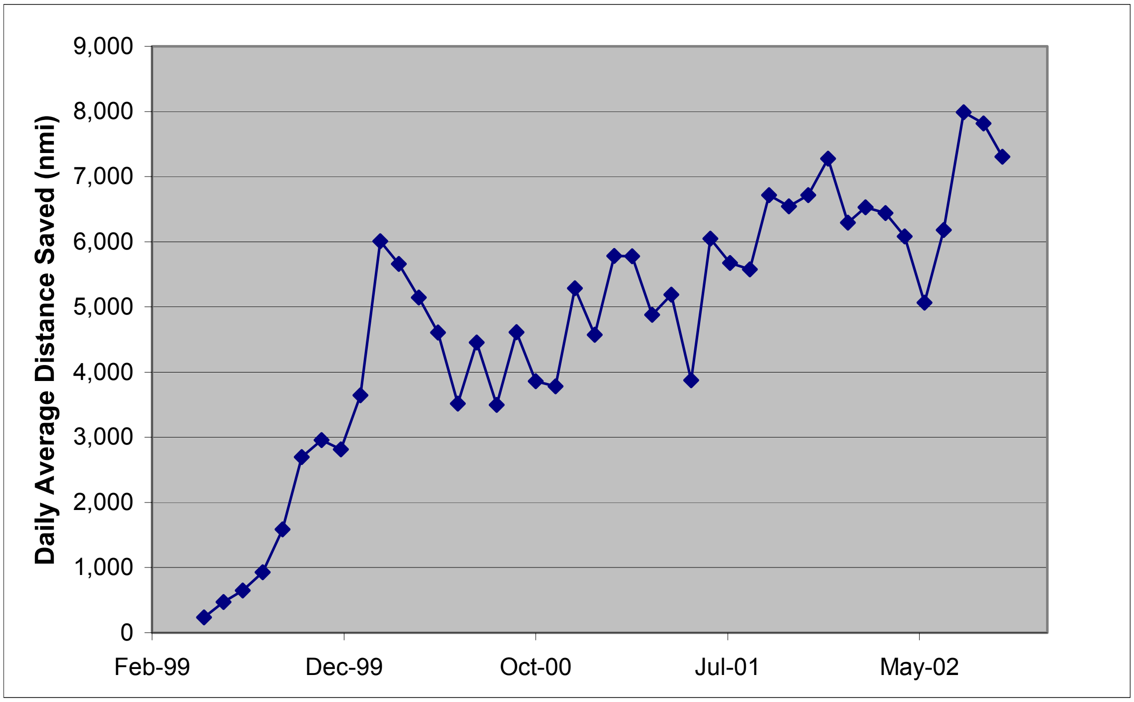
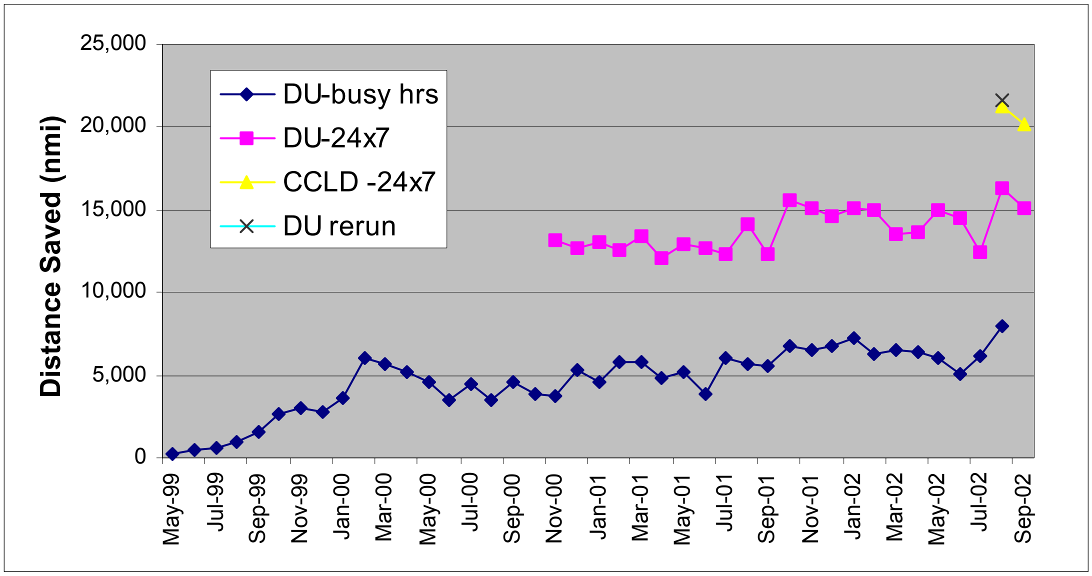


Fig 2-10. Distance Saved at ZID (prototype)

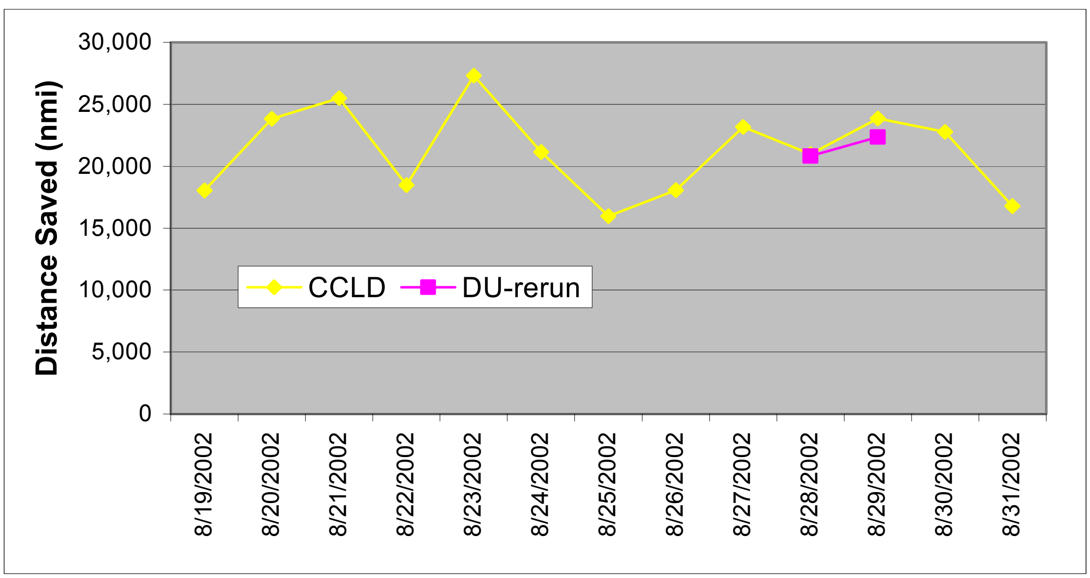
CCLD sites began collecting lateral savings data in August 2002. Distance savings results for CCLD differ from those found for the prototype in a way that is well understood. Figure 2-11 shows a comparison of the lateral amendment data from ZID as computed by the prototype, labeled DU (for *Daily Use*), and those from CCLD. The lower curve is the savings computed in the same way as presented in previous reports, and it lies nearly a factor of four below the CCLD data, shown by the yellow triangular symbols. However, this data was computed for only the busy hours in the day, whereas the CCLD data was computed for the full 24 hours. The DU data was recalculated for the full day, and the results (shown by the square pink figures) are much closer to the CCLD data than previously.

A second correction is needed to bring the DU and CCLD data in line. The prototype did not handle Standard Terminal Arrival Routes (STARs) properly in the calculation of the distance-saved metric, leading to an underestimate of the savings. Figure 2-12 shows the prototype results recomputed for two days in August 2002 with STARs handled properly. The average of the two days data was taken to be the monthly value, which is plotted in Fig. 2-11 with crosses and labeled "DU rerun." This data agrees very well with the August value reported by CCLD.



Comparison of CCLD and DU data, showing the difference between DU taken for busy hours versus 24 hours, and DU data rerun to properly include STARs.

Fig 2-11. Distance saved comparison of DU and CCLD



Comparison of daily CCLD and DU results from ZID for August 2002, where DU data was reanalyzed for two days with proper inclusion of STARs.

Figure 2-12. Distance Saved from Lateral Amendments

2.3.4 Wind-Adjusted Flight Times for Selected City Pairs

Previous semi-annual metrics reports have included analyses of the impact of URET on en route flight distance between selected city pairs. In particular, in the December 2001 report, en route flight distances for flights traversing ZID and ZME airspace were shown to be decreasing since the onset of two-way Host/URET communications in July 1999. Full details on these results and the analysis methodology can be found in [6].

In this report, we will expand on the en route distance analysis by looking at en route flight times. Ideally, en route times can present a more direct measure of user operating costs than en route distances. However, flight times vary substantially because of winds, and this variance obscures incremental improvements in routing efficiency. For this reason, we have generally used distance flown as the preferred metric for assessing changes in routing efficiency. For this analysis we introduce a wind-adjustment technique that greatly reduces the variance in flight times, allowing a more robust assessment of efficiency-related changes in flight times.

2.3.4.1 Wind Adjustment Methodology

En-route flight times for a given city pair typically display a strong seasonal variation, with a negative correlation between the different directions of flight for the pair (i.e., when flight times are high for the "from A to B" flights, they are typically low for the "from B to A" flights). This results from the fact that the headwind component is a dominant factor in the observed flight times. In this report, we describe a technique that uses the negative correlation between directions of flight for a city pair to (approximately) adjust for the wind effects.

As an example, consider a situation where winds are exactly aligned with the direction of flight for aircraft traveling from A to B. For each direction, we can calculate an observed ground speed by dividing the actual distance flown by the actual flight time. This observed ground speed is related to the aircraft's air speed and the wind speed by:

$$\text{From A to B}: \quad v_{ground} = v_{air} + v_{wind}$$

$$\text{From B to A}: \quad v_{ground} = v_{air} - v_{wind}$$

Thus, in this idealized example, the average ground speed for both directions is equal to the air speed. If we divide the actual distance traveled for each direction by this calculated air speed, we can remove the effect of the wind and extract a wind-adjusted flight time for each direction.

For real-world data, this methodology provides a way to approximately correct for winds. This correction is not exact, and it requires several simplifying assumptions; nevertheless, as we will show, the method greatly reduces the variance in flight times. The assumptions made are:

- Flights from A to B travel the same path as flights from B to A
- The average air speed is the same for flights in both directions
- The effect of crosswinds on flight times is negligible.

As described in [6], we are considering only the en route portion of flights, i.e., only those portions of the flight greater than 40 nmi from either the departure or arrival airports. Thus, although our first assumption about identical paths may never be completely valid, it may provide a reasonable approximation since we are not considering local deviations related to arrival or departure procedures. Moreover, the actual distance flown for each flight is used to calculate the wind-adjusted flight time; the assumption only requires that, in the mean, the effect of the wind on the "to" flights is the opposite of the effect of the wind on the "from" flights.

An example of the application of this technique to real world data is shown in Figures 2-13 and 2-14. In the figures, actual en route flight times are shown as open symbols, while the wind-adjusted flight times are shown as closed symbols joined by lines. Each point represents an average over a single day's flights for that city-pair and direction. The actual flight times demonstrate a strong seasonal variation, as well as a pronounced negative correlation between the two directions. The variation in wind-adjusted times is significantly less than that of the actual times. Further, anomalously large flight times stand out much more clearly in the wind-adjusted times than in the actual times. There are several examples of large wind-adjusted flight times in DFW-ORD times as shown in Figure 2-14; for these examples, the actual flight times are not obviously unusual, but a closer look at the data shows that in each case, the distance flown was significantly higher than the average. A simple analysis of the distance flown data would have shown these days to be unusual, but interpretation of that finding would have been ambiguous, since it would have been possible the extra distance had been undertaken in order to achieve a wind-optimal flight path. The wind-adjusted times allow an unambiguous identification of these days as having unusually high flight times.

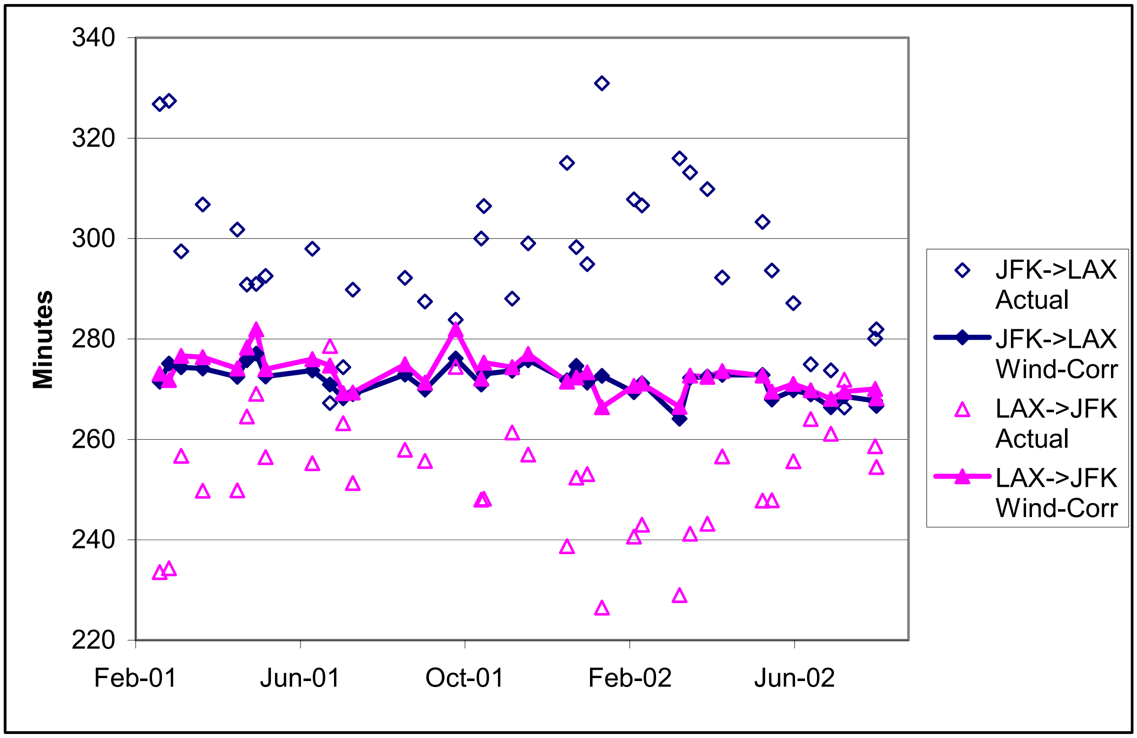


Figure 2-13. Actual and Wind-Adjusted Flight Times, JFK to/from LAX

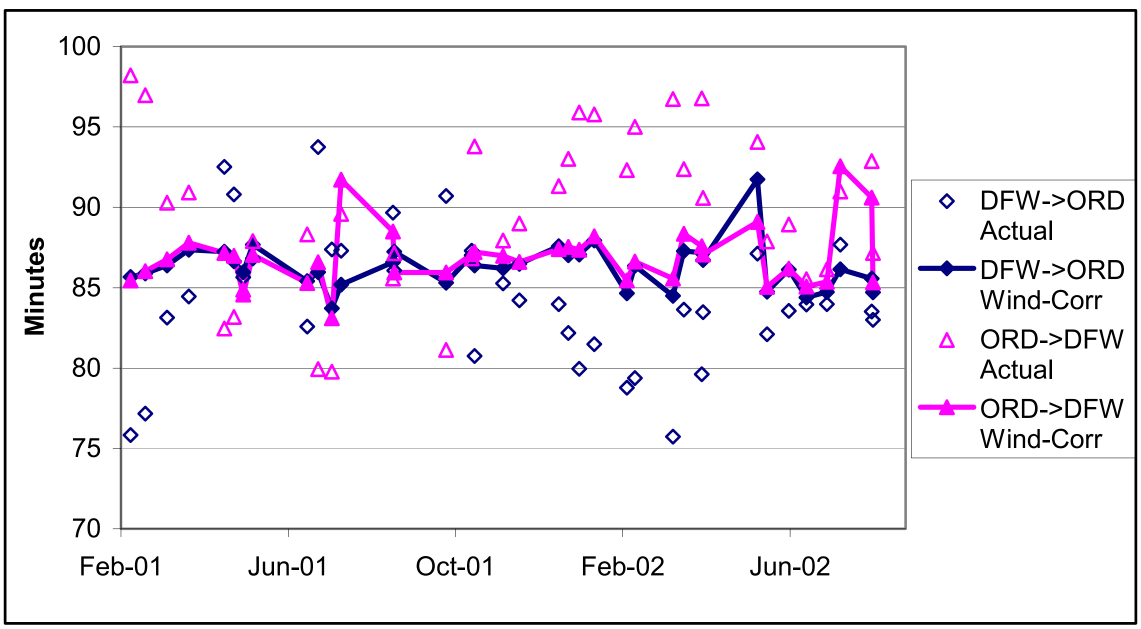


Figure 2-14. Actual and Wind-Adjusted Flight Times, DFW to/from ORD

2.3.4.2 Results for Free Flight Phase1 URET CCLD Centers

Over the last year four new ARTCCs (ZOB, ZAU, ZKC and ZDC) have implemented URET. Initial Daily Use (IDU) dates for these centers are given in Table 2-1.

Table 2-1. Dates for Initial Daily Use (IDU) and Sample Periods

ARTCC	IDU Date	Pre-URET Period	Post-URET Period
ZKC	December 3, 2001	Feb. to Aug., 2001	Feb. to Aug, 2002
ZOB	January 28, 2002	Feb. to Aug., 2001	Feb. to Aug, 2002
ZAU	February 25, 2002	Mar. to Aug., 2001	Mar. to Aug., 2002
ZDC	April 12, 2002	May to Aug., 2001	May to Aug., 2002

We have applied the flight time wind-adjustment methodology to data for the four new Free Flight Phase 1 CCLD Centers with the goal of assessing the impact of URET on those sites. As described in previous reports and [6], city pairs have been chosen that traverse the air space of those centers. Actual flight times and flight distances have been collected for flights between these city pairs for a number of sample days; typically, two to three weekdays per month have been sampled for the period February 2001 through August 2002. We have averaged wind-adjusted flight times for all available days after IDU for each center to arrive at a post-URET value for each of the selected city pairs. For comparison, we would like to have similar time frames so as to avoid seasonal effects. Thus, for each Center we sampled the previous year's data for the same months included in the post-URET sample. The dates included are outlined in Table 2-1.

A comparison of average wind-adjusted flight times, actual flight times and actual flight distances for pre- and post-URET periods is shown in Table 2-2. In the "Change" column for each metric, a decrease in the time or distance is highlighted. Both ZOB and ZAU consistently show decreases in wind-adjusted times—for ZOB, all eight city pairs showed decreases, while for ZAU, 8 of 9 city pairs showed decreases. Averaged over all of the selected city pairs, ZOB and ZAU showed decreases of 1.4 and 0.6 minutes, respectively. There appeared to be no observable change in the wind-adjusted times for ZKC and ZDC, with the average change for their selected city pairs very near to zero.

Table 2-2. Wind-Adjusted Flight Times, Actual Flight Times, and Actual Flight Distances in En Route Airspace for Selected City Pairs

Center	City Pair	Wind-Adjusted Times (Minutes)			Actual Times (Minutes)			Actual Distance (n. mi.)		
		Pre-URET	Post-URET	Change	Pre-URET	Post-URET	Change	Pre-URET	Post-URET	Change
ZOB	BOS to ORD	94.2	94.1	-0.1	100.1	103.1	3.0	690.9	691.6	0.7
	ORD to BOS	94.7	92.5	-2.2	90.0	85.7	-4.2	694.5	679.7	-14.9
	JFK to LAX	272.9	269.4	-3.5	296.6	293.3	-3.3	2100.2	2095.5	-4.7
	LAX to JFK	274.7	270.4	-4.2	255.4	251.1	-4.4	2113.5	2103.8	-9.7
	PIT to ORD	40.7	40.7	-0.1	44.6	44.7	0.1	287.4	288.5	1.0
	ORD to PIT	40.7	40.4	-0.2	37.8	37.4	-0.5	286.8	286.6	-0.2
	PHL to ORD	74.6	74.1	-0.5	80.2	80.4	0.2	531.0	530.2	-0.7
	ORD to PHL	73.0	72.7	-0.3	69.0	67.9	-1.1	519.8	520.5	0.7
ZOB	Average	120.7	119.3	-1.4	121.7	120.5	-1.3	903.0	899.5	-3.5
ZAU	DTW to MSP	55.2	54.8	-0.4	60.3	59.9	-0.5	400.9	400.7	-0.2
	MSP to DTW	54.8	54.6	-0.3	50.9	50.6	-0.3	398.2	399.1	0.8
	ORD to MSP	38.8	38.9	0.1	41.1	41.0	-0.1	266.0	267.7	1.7
	MSP to ORD	32.5	32.2	-0.2	30.9	30.9	0.0	222.9	221.9	-1.0
	ORD to DEN	93.7	92.9	-0.8	99.6	100.2	0.6	704.5	701.1	-3.3
	DEN to ORD	97.1	96.0	-1.0	92.0	90.0	-2.0	730.1	725.1	-5.0
	ORD to LAX	190.4	189.6	-0.9	201.9	203.5	1.6	1452.5	1451.9	-0.6
	LAX to ORD	193.5	192.1	-1.4	183.5	180.3	-3.2	1476.0	1471.5	-4.5
	DFW to ORD	86.6	86.2	-0.3	88.5	83.9	-4.6	638.6	636.6	-2.1
ZAU	Average	93.6	93.0	-0.6	94.3	93.3	-0.9	698.9	697.3	-1.6
ZKC	ATL to DEN	130.1	130.3	0.1	139.9	141.0	1.1	983.1	982.1	-1.0
	DEN to ATL	129.1	129.9	0.8	121.2	121.5	0.3	975.4	979.8	4.4
	ORD to DFW	86.6	87.1	0.5	87.5	91.2	3.7	639.4	643.0	3.6
	DFW to ORD	86.2	86.1	-0.1	85.9	82.5	-3.4	636.1	635.0	-1.2
	ORD to IAH	104.1	104.3	0.2	102.9	106.6	3.7	762.9	762.6	-0.4
	IAH to ORD	102.7	103.0	0.3	104.5	101.0	-3.5	752.4	752.8	0.5
	MCI to DFW	48.1	48.6	0.5	48.3	50.3	2.0	352.9	351.5	-1.4
	DFW to MCI	45.3	46.0	0.7	45.4	44.5	-0.8	331.9	332.4	0.5
	STL to PHX	142.8	141.2	-1.6	152.6	154.3	1.7	1045.2	1036.8	-8.5
	PHX to STL	139.9	139.5	-0.4	132.2	129.4	-2.7	1023.5	1023.9	0.4
ZKC	Average	101.5	101.6	0.1	102.0	102.2	0.2	750.3	750.0	-0.3
ZDC	EWR to MCO	103.4	103.6	0.2	106.6	101.5	-5.1	767.6	769.0	1.3
	MCO to EWR	103.8	104.6	0.8	101.1	107.5	6.3	770.5	776.5	5.9
	EWR to ATL	78.3	78.7	0.4	80.7	76.9	-3.8	578.8	579.8	1.1
	ATL to EWR	80.1	80.1	0.0	77.9	82.5	4.6	592.0	590.1	-1.9
	LGA to CLT	56.1	55.1	-1.0	57.6	53.0	-4.6	400.6	400.4	-0.2
	CLT to LGA	57.7	56.7	-1.0	56.4	59.2	2.8	411.9	412.1	0.2
	PHL to ATL	69.7	70.2	0.4	71.7	68.7	-3.1	512.4	516.5	4.1
	ATL to PHL	70.9	70.7	-0.2	69.1	72.8	3.7	521.0	520.8	-0.2
ZDC	Average	77.5	77.5	0.0	77.6	77.8	0.1	569.4	570.7	1.3

Shaded cells indicate reductions in the various metrics/city pairs.

The decrease in wind-adjusted flight times during the pre- and post-URET periods in two of four Centers is encouraging. However, other factors may have contributed to this decrease, including an overall decrease in traffic during the post-URET period (2002 versus 2001). Thus, it is not clear that the decrease can be unambiguously associated with URET. Further monitoring of the metrics may allow a more definitive conclusion.

Regardless of the interpretation of the analysis, we consider the exercise of applying the wind-adjusted flight time methodology as a success. As might be expected, the changes in wind-adjusted flight times showed considerably less variance (over the full data set) than did the changes in actual flight times or distances. Thus, as a metric, wind-adjusted flight times are more likely to be sensitive to the incremental efficiency improvements we expect from the tools we are evaluating.

3.0 TRAFFIC MANAGEMENT ADVISOR (TMA)

The Center-TRACON Automation System consists of two major components. Traffic Management Advisor is currently operational at Ft. Worth, Minneapolis, Denver, Los Angeles, Atlanta, Miami, and Oakland ARTCCs. After extensive testing at the Dallas/Ft. Worth TRACON, activity on the TRACON component of CTAS, the Passive Final Approach Spacing Tool (pFAST), was terminated because of the tool's inability to function adequately in dynamic situations. An alternative component, CTAS-Terminal, was developed and is in use at the Southern California TRACON (SCT).

This section describes the operational use of TMA, outlines the analyses used in measuring benefits, and presents some results. More specifically, the results include a summary of previous findings for Ft. Worth, Minneapolis, Denver, Los Angeles, Miami, and Atlanta Centers; an updated analysis of the effects of CTAS on acceptance rates, actual arrival rates, and flight distances at Los Angeles Center and Southern California TRACON; an introductory study of holding at Atlanta; an introductory study of flight distances at San Francisco, and an updated analysis of internal departure delay; and an introductory study of flight times and distances at Miami, along with an updated examination of internal departure delay.

3.1 Description

TMA assists controllers in the en route cruise and transition airspace managed by Air Route Traffic Control Centers. TMA provides ARTCC personnel with a means of optimizing the arrival throughput of capacity-constrained airports. By optimizing throughput, TMA helps to reduce arrival delays. The resulting uniformity of arrival flows can also lead to an increase in departure rates and a decrease in departure delays.

Inputs to the TMA system include real-time radar track data, flight plan data, and a three-dimensional grid of wind speeds and directions. TMA's trajectory models use this information, updated every 12 seconds, to compute routes and optimal schedules to the meter fixes for all arriving aircraft which have filed Instrument Flight Rules (IFR) flight plans, with consideration given to separation, airspace, and airport constraints. These optimized schedules may then be displayed on controllers' radar displays, and used to ensure a smooth and efficient yet safe flow of aircraft to the terminal area.

3.2 Summary of Previous TMA Results

TMA was initially implemented at Ft. Worth Center (ZFW) before the establishment of the Free Flight Phase 1 program, concurrent with the redesign of Dallas/Ft. Worth (DFW) terminal airspace, so no applicable baseline data is available for this site. The impact of TMA at Dallas/Ft. Worth was analyzed by the NASA Ames Research Center [7], and was discussed in the June 2000 metrics report [5]. No further analysis of this site is envisioned.

Denver Center (ZDV) began IDU of TMA for arrivals at Denver International Airport (DEN) in September 2000. Although controllers employ time-based metering at DEN, airport capacity is such that the facility does not require it on a regular basis. In order to study the effect of TMA, we limited the times of study to those in which the airport was heavily stressed. In the December 2001 report [4], we presented an analysis of the arrival peaks during times of high airport stress, which showed that the arrival rate increased by 1 to 2 aircraft an hour after introduction of TMA. Most of the time, air traffic managers use TMA to make strategic decisions about miles-in-trail (MIT) restrictions. We expect that benefits due to TMA will increase at ZDV/DEN as demand increases.

At Minneapolis Center (ZMP), TMA is used both as a strategic planning tool by the Traffic Management Unit (TMU) and tactically by controllers who are actively controlling aircraft using time-based metering. IDU of TMA at ZMP for Minneapolis International Airport (MSP) began in June 2000. An analysis of TMA presented in the June 2001 metrics report [2] concluded that operations rates increased by approximately three an hour during arrival peaks. The analysis also revealed a decrease in flight times close to the terminal area during arrival peaks, which correlates to an increase in efficiency. This analysis was updated in the December 2001 metrics report [4] to show the continuation in throughput and efficiency benefits, even after the decrease in demand after September 11th. The June 2002 report [3] described an increase in the AAR at MSP of 1.4 arrivals per hour in instrument conditions and 0.7 arrivals per hour in visual conditions after the installation of a TMA TRACON feed.

A terminal version of CTAS was first implemented at Southern California TRACON (SCT) in February 2001 and TMA (without time-based metering) started IDU at Los Angeles Center (ZLA) in June of 2001. A preliminary analysis of CTAS at ZLA and SCT for arrivals at LAX was presented in the June 2001 metrics report. The throughput analysis showed an increase in the difference between the actual arrival rate and the AAR for peak periods. Efficiency analyses presented in the June 2001 report showed a slight decrease in the flight times and distances for arriving traffic during peak periods, and a queuing study that indicated an average decrease in delay of 1.63 minutes after CTAS implementation. An update of the throughput analysis, presented in the December 2001 report, concluded that arrival throughput at LAX had increased between one and two airplanes an hour during the peaks. Also, in the December 2001 report, we probed efficiency by examining individual tracks to show a decrease in holding. We also showed a decrease in delay for internal departures resulting from TMA. In the June 2002 report, we updated the arrival throughput analysis confirming that the peak arrival rate continues to show an increase between one and two arrivals an hour after CTAS implementation. In the June 2002 report, we also explored the acceptance rate at LAX, showing that the AAR increased approximately one aircraft per hour during instrument conditions. In this report, we update the throughput analysis focusing on the recent implementation of time-based metering at ZLA for LAX arrivals.

At Miami center (ZMA), TMA started IDU in May 2001 for arrivals into Miami International Airport (MIA). TMA is currently used only as a strategic tool for traffic managers. Prior to TMA daily use, the TRACON kept the AAR at a consistent 62 arrivals per hour. Because of the increased coordination between the TRACON and the Center after TMA, MIA began to change the AAR based on airport and meteorological conditions. In the June 2002 report, we showed that the average AAR increased from 62 to 66 an hour since TMA, indicating a larger potential capacity at the airport. In May

2002, MIA started calling rates as high as 72 and received actual arrival counts as high as 74 an hour. These results imply a potential for a sustained throughput increase as demand levels continue to rise.

In addition to time-based metering, TMUs have discovered another mechanism by which TMA can positively effect airport arrivals. For internal departures bound for TMA airports that require release by the center, the TMA "Departure Scheduler" provides a suggested departure time for each arrival route, and calculates the imparted delay needed to fit the aircraft into the arrival flow for the selected fix. The Traffic Management Coordinator (TMC) uses this information to make informed decisions on when to release aircraft, or whether to reroute aircraft. Additionally, the TMA time-lines provide visual cues to the TMC for affected airports and proposed departure times. In the June 2002 report, we calculated average gate and airborne delay per flight for flights from the airports that require a release by ZLA, ZTL, ZMA, and ZOA for departures to LAX, ATL, MIA, and SFO respectively. Average gate delay for internal departures decreased between one and four minutes at all four airports studied. The decrease was largest at LAX, where a CTAS tool had been in place for the longest time (since February 2001), while the smallest decrease was evident at SFO, the airport that started IDU most recently (September 2001). The effect of TMA on airborne delay is somewhat more ambiguous. ATL, MIA, and SFO airports saw a decrease in airborne delay for internal departures since TMA IDU, while LAX has seen a very slight increase (less than half a minute). In this report we update the internal departure analysis.

3.3 TMA at ZLA/LAX

Active use of TMA started at ZLA for LAX arrivals in June 2001. However, until mid-May 2002 TMA was primarily a strategic tool used by ZLA traffic managers to determine the necessity of location-based miles-in-trail (MIT) restrictions. The overlay list that allows tactical use of the tool by individual controllers was not in use at ZLA because the Center was not using time-based metering. A cadre of personnel at ZLA conducted an operational suitability assessment of time-based metering with TMA between May and July 2002. Additional operational testing was performed in August and September 2002, and currently all controllers in two areas are undergoing on-the-job training between 9:00 and 12:00 PST, Monday through Friday. It is expected that ZLA will fully employ time-based metering at all positions by June 2003.

We examine here the results of the time-based metering operational suitability assessment of May-June 2002.

3.3.1 Airport Acceptance Rate and Throughput Analysis

In order to assess terminal capacity effects of ZLA time-based metering (TBM), we investigated changes in both acceptance rates and actual arrival throughput at LAX. First, we discuss changes in Airport Acceptance Rate (AAR). We considered two time periods for comparison: a one and a half month period prior to implementation of TBM (2 April to 10 May 2002), and a TBM operational period of similar duration (14 May to 28 June 2002). Each period considered only Tuesdays through Fridays from 8:00 AM to 12:00 PM local time, the hours TBM was used. Data sources available were the Free

Flight Office's internal metrics database, used in this study, and the ASPM database; both show similar results.

Similar to the analysis of LAX in [3], we first considered the effects of certain variables on AAR. These variables included the type of approach used (instrument or visual), implementation of TBM, interaction between the two (IFR*TBM), airport configuration (East/West), percentage of heavy aircraft in the time period, and some relevant meteorological conditions (precipitation, ceiling, etc.). A preliminary linear regression analysis was performed to investigate these relationships. Previous reports concluded that the AAR was strongly and negatively influenced by the *East* configuration of the airport runways. For the time periods considered in this study, only a single one-hour period was in the *East* configuration; therefore this variable was excluded. Due to low significance, other variables were also excluded from the final AAR regression: percentage of heavy aircraft, visibility, and wind speeds. Though the interaction of the instrument approach and TBM implementation seemed intuitively significant, the preliminary regression analysis showed that it is not; the interaction is therefore excluded in the finalized analysis.

Table 3-1 displays the results of the final regression of the AAR. The regression results suggest that when TBM was utilized the overall AAR increased by slightly less than one aircraft per hour. As expected, the IFR approach condition caused a significant decrease in the AAR of nearly eight aircraft. The contribution from the ceiling variable was significant and contributes an increase of one to the AAR as the ceiling approaches 15,000 feet. However, if the regression is used to determine the overall effect of TBM implementation during instrument conditions, the ceiling variable is negligible.

Table 3-1. LAX Airport Acceptance Rate Regression

Dependent Variable: AAR

R Square	Adjusted R Square	F	Sig.
.583	.582	386.318	.000

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	74.700	.395		188.913	.000
TBM	.579	.250	.052	2.317	.021
IFR	-7.580	.321	-.633	-23.630	.000
Ceiling	6.75E-05	.000	.198	7.415	.000

	Explanation of Variables
TBM	0 = Pre-TBM, 1 = During-TBM
IFR	0 = Visual Approaches, 1 = Instrument Approaches
Ceiling	Ceiling in feet with unlimited ceiling replaced with 35,000ft.

We next considered actual peak arrival rates observed at LAX. The time periods remain the same as those in the AAR analysis. Additionally, we considered corresponding variables as in the AAR regression analysis; the variables of significance for called acceptance rates must logically be the same as those for actual arrivals.

In this analysis, peak periods are defined as those where actual arrival rates are greater than or equal to eighty percent of the AAR, in fifteen-minute bins. Figure 3-1 depicts the mean peak arrival rates before and during TBM implementation for both approach types. Additionally, this figure depicts the 95 percent confidence intervals for our dataset. For instrument conditions, which have mean values of 14.2 and 15.0 for "Before" and "During" periods, respectively, the difference in means is statistically significant. However, the difference in means for visual approaches is not statistically significant. This straightforward analysis indicates that peak arrivals rates under instrument approaches have increased approximately 5 percent as a result of TBM implementation.

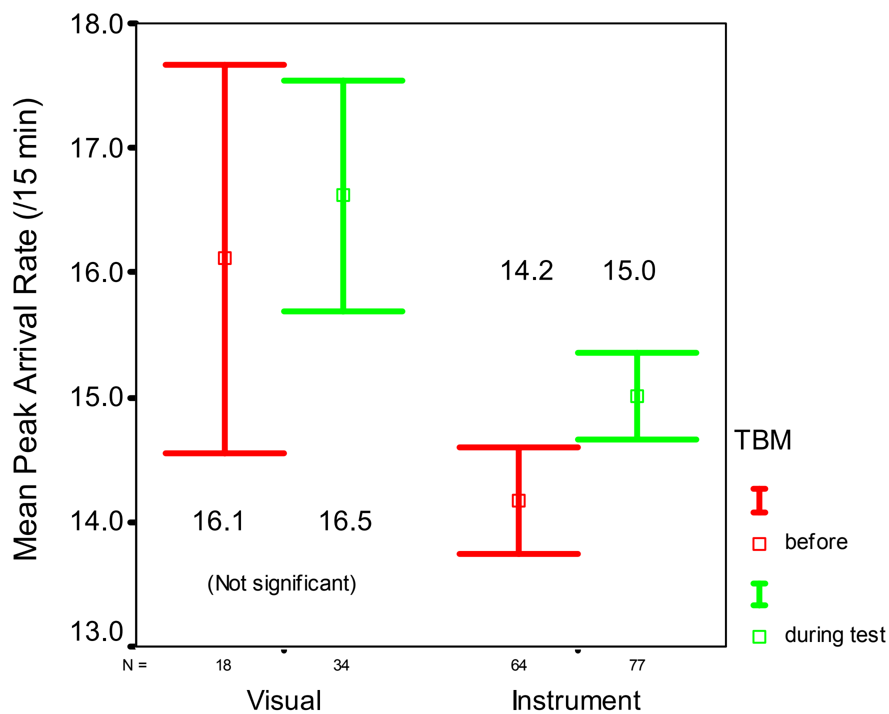


Figure 3-1. Actual Arrival Rates

To support our result, we continue with a regression analysis on the actual arrival rates during peak periods. Table 3-2 displays the regression results. It should be noted that the regression of Table 3-2 is for 15-minute periods, as compared to one hour periods of Table 3-1; coefficients of Table 3-2 should therefore have a multiplier of four. The adjusted R^2 indicates that only 40 percent of the variation in the dependent variable is accounted for by this model, but the F statistic indicates that the regression is indeed significant. As expected, the instrument approach condition causes the rate of arrivals to decrease by approximately eight aircraft per hour. Implementation of the TBM tool increases the arrival rates by more than two aircraft each hour during peak periods. Consideration of the cloud layer (ceiling), though statistically significant, has a negligible contribution to the regression during instrument conditions, as was seen before. Although the regression results show a slightly lower increase than that of Fig.3-1 under IFR, the increase of actual arrivals applies to both IFR and VFR approaches. Clearly, though more factors need to be considered for better modeling, the regression results indicate an increase in peak arrival throughput as a result of TBM use.

Table 3-2. LAX Actual Arrival Rate Regression

Dependent Variable: Actual Arrival Rate

R Square	Adjusted R Square	F	Sig.
.397	.391	67.515	.000

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	16.419	.259		63.392	.000
TBM	.571	.156	.163	3.663	.002
IFR	-1.935	.207	-.504	-9.367	.000
Ceiling	1.43E-05	.000	.135	2.513	.012

	Explanation of Variables
TBM	0 = Pre-TBM, 1 = During-TBM
IFR	0 = Visual Approaches, 1 = Instrument Approaches
Ceiling	Ceiling in feet with unlimited ceiling replaced with 35,000ft.

3.3.2 Flight Distance Analysis

In addition to examining airport throughput, we also analyzed track data to determine arrival aircraft flight distances in SCT airspace. We typically want to study both the capacity of terminal airspace (approximated by peak period throughput), and the efficiency of the airspace, as indicated by the time of flight from some reference point to the runway. Since time of flight is highly dependent on wind speed and direction, which is difficult to statistically control for in the terminal area, we frequently use flight distance as a surrogate metric. For this analysis the flight paths of arriving aircraft were segmented by various range rings centered on LAX. The rings used are:

- Extreme Arc (EA) at 200 nmi
- Outer Arc (OA) at 106 nmi

- Inner Arc (IA) at 70 nmi (not shown in Fig. 3-2)
- Meter Arc (MA) at 50 nmi
- Final Arc (FA) at 24 nmi.

Figure 3-2 shows a simple map of Southern California with the outline of SCT, as well as the placement of the rings and the location of some area airports. ARTS data was used for calculation of the average flying distances between each successive pair of rings for planes that landed during stressed periods at LAX. Stressed periods were determined by first computing airport arrival rates using the ARTS data, then isolating times when the arrival rate was greater than the average rate for the day. Since the greatest throughput increase was during instrument conditions, we limited to 68 the maximum AAR used.

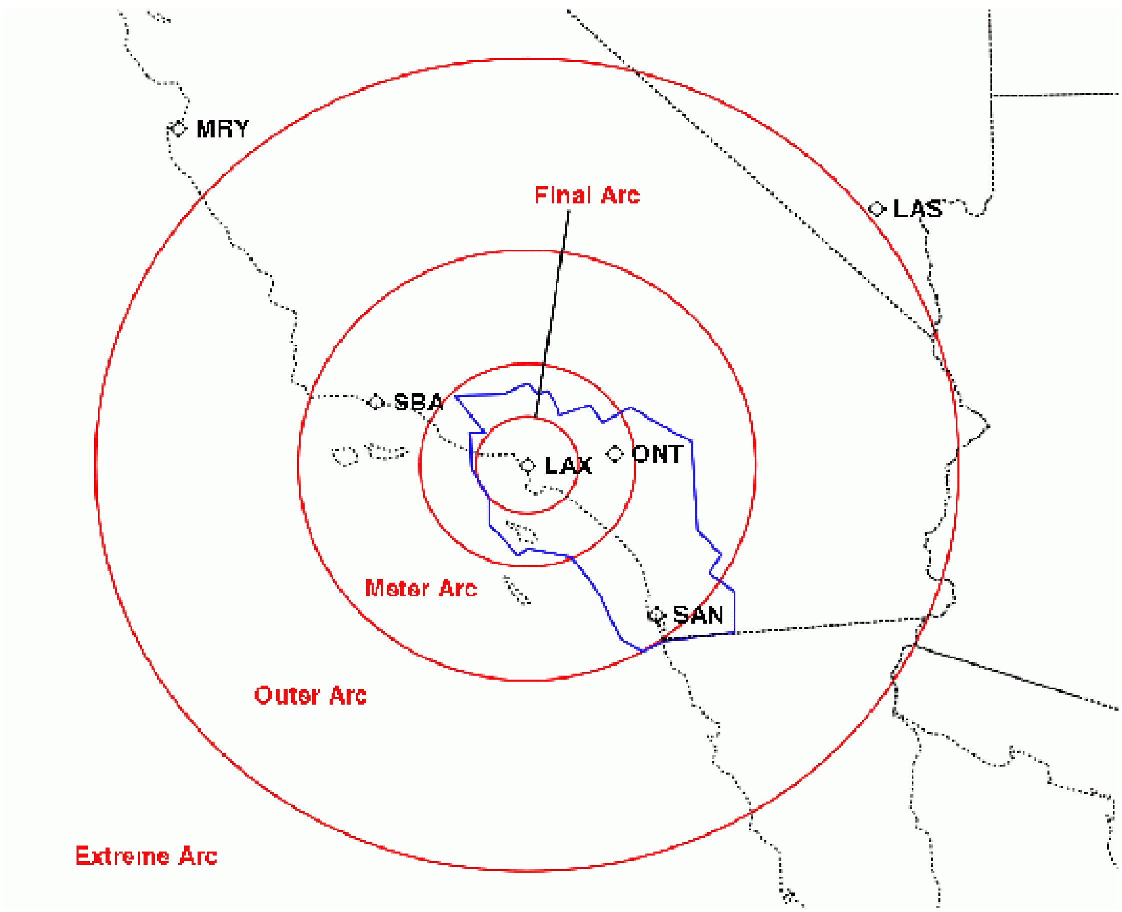


Figure 3-2. LAX Range Rings for Flight Distance Metrics

We first examined flight distances from the Outer Arc to the Meter Arc. Figure 3-3 portrays the mean flight distances from the Outer Arc to the Inner Arc, and from the Inner Arc to the Meter Arc, from April through June 2002. Means are presented for both metered and unmetered arrivals.[2] Confidence intervals around these means are also depicted, and sample sizes are shown at the bottom of the chart. There was obviously little change in flight distances outside of the Meter Arc with the use of time-based metering. The small differences depicted in Figure 3-3 are *not* statistically significant.

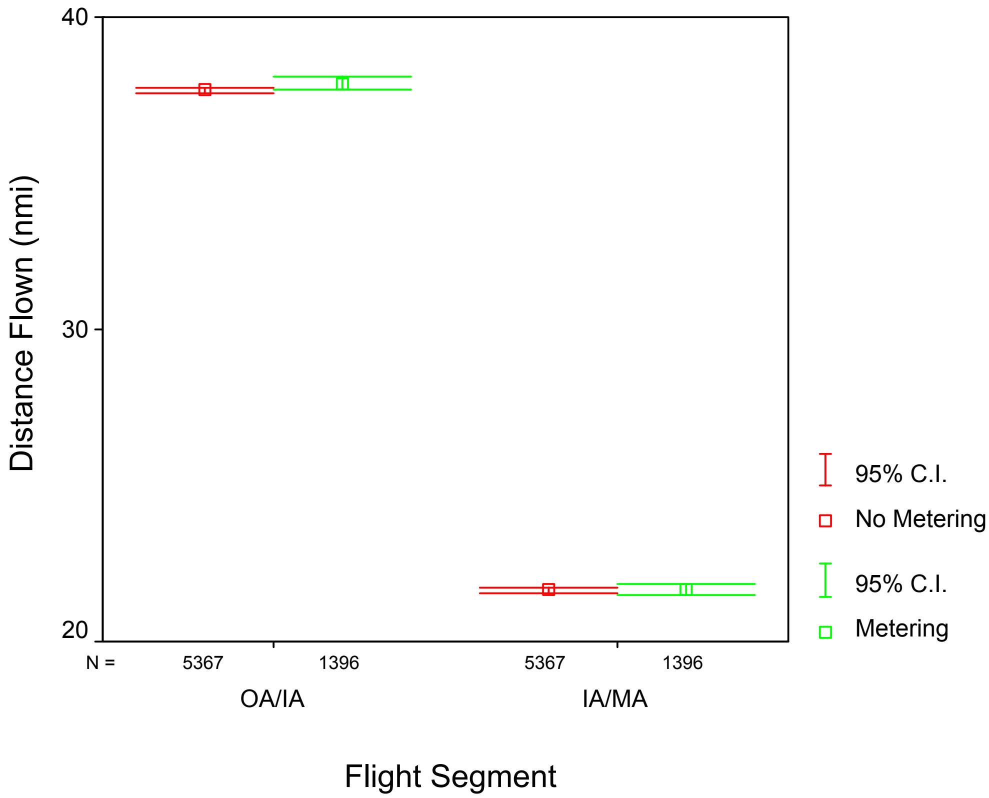


Figure 3-3. LAX Arrival Flight Distance Comparison, OA to MA

We also examined the variation of flight distances from the Outer Arc to the Meter Arc. Figure 3-4 presents the standard deviation of the samples whose means were presented in Figure 3-3. There was apparently a large increase in variation in flight distances from the Outer Arc to the Inner Arc during the time-based metering assessment, although there was little change from the Inner Arc to the Meter Arc.

We next examined flight distances inside the Meter Arc. Figure 3-5 presents the mean flight distances from the Meter Arc to the Final Arc, the Final Arc to the runway, and the sum of the two, along with 95 percent confidence intervals about the means. There is a small but statistically significant decrease in flight distances from the Meter Arc to the runway for the time-based metering arrivals. This difference is mainly found in the segment from the Meter Arc to the Final Arc, where there is also a small and statistically significant decrease. As the figure indicates, there has not been any significant change in flight distances from the Final Arc to the runway.

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[2] Prior to 14 May 2002 all arrivals were unmetered. Between 14 May and 28 June 2002 there is a mix of both metered and unmetered arrivals.

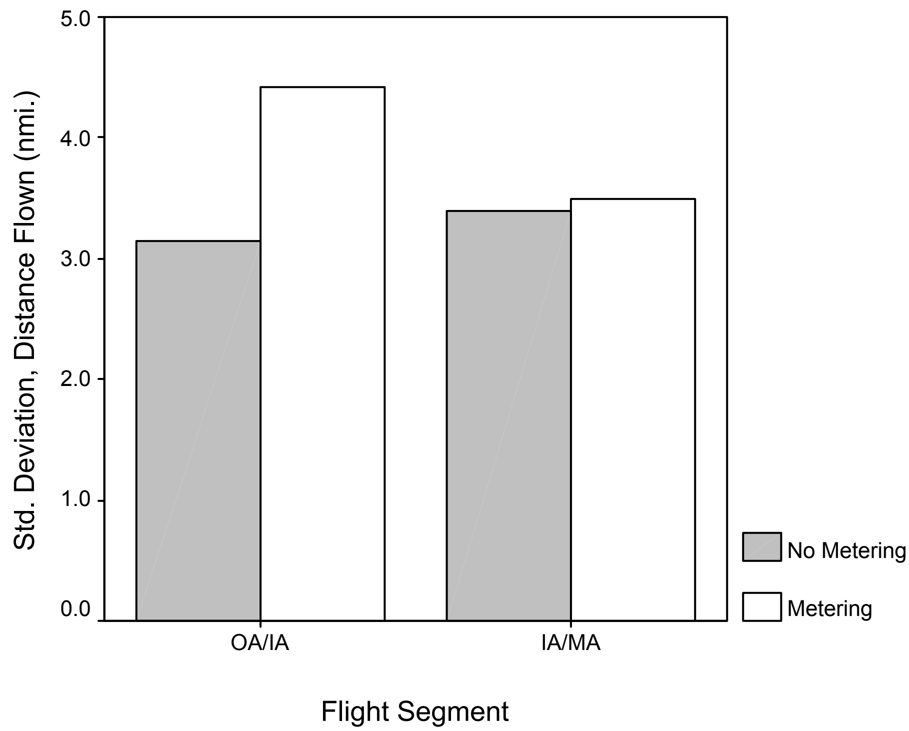


Figure 3-4. LAX Arrival Flight Distance Comparison, OA to MA, Standard Deviation

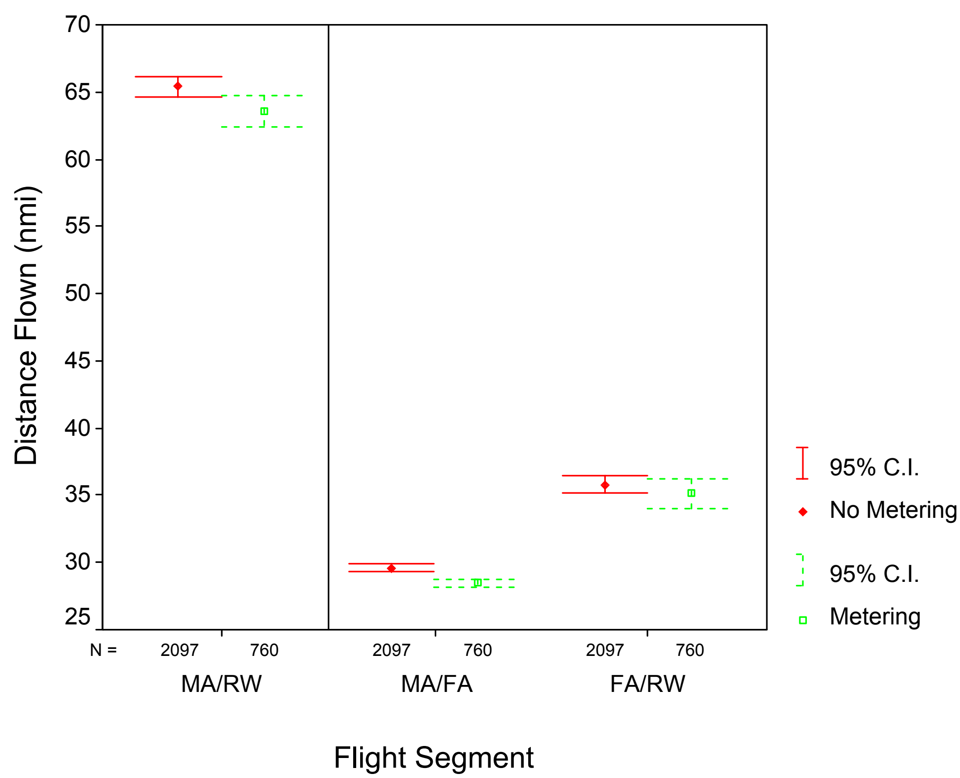


Figure 3-5. LAX Arrival Flight Distance Comparison, MA to Runway

Figure 3-6 presents the standard deviation of flight distances from the Meter Arc to the runway. As can be seen, there was a small decrease in the standard deviation from the Meter Arc to the Final Arc with time-based metering. This decrease more or less offsets the observed increase in the standard deviation from the Outer Arc to the Inner Arc.

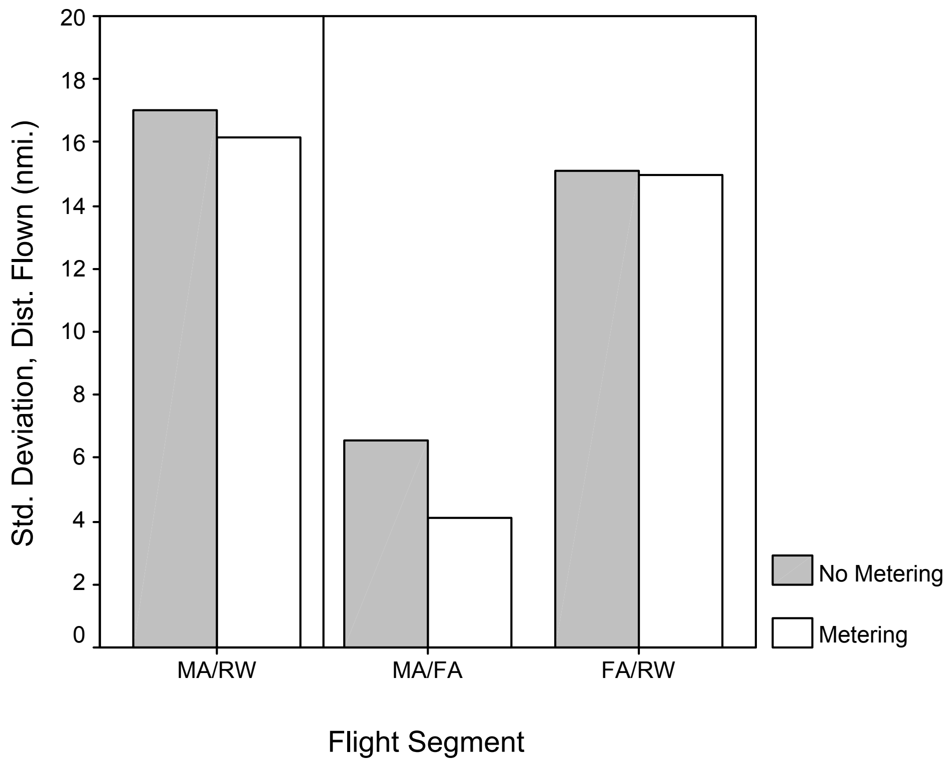


Figure 3-6. LAX Arrival Flight Distance Comparison, MA to Runway, Standard Deviation

Finally, in order to see if there was a time trend in the flight distance that might be lost in the above comparisons of means, we performed a regression analysis on flight distance. Each observation for this regression was an individual arriving flight. The dependent variable in this regression was the distance flown from the Meter Arc to the Final Arc, and the independent variables were the Julian day of the observation and a dummy variable representing time-based metering. We extended the observation period through 10 August 2002 for this analysis in order to capture any change after the conclusion of the time-based metering experiment, and thus ensure that a time trend was not confused with a true effect of time-based metering.

The linear regression was performed with “DAY” and “TBM” (implementation) as dummy variables. The DAY variable was not statistically significant, indicating that there is no underlying time trend and thus supporting the previous comparison of means.

3.4 TMA at ZTL/ATL

Initial Daily Use of TMA at Atlanta Center commenced in February 2001. At the outset, a cadre of traffic managers used the tool to increase their situational awareness. By June 2001 all traffic managers had been trained in the use of the tool and were using it for various management functions. ZTL Center has not yet implemented time-based metering, so TMA delay advisories are not being displayed on the radar displays. A cadre of controllers is scheduled to begin training in time-based metering in April 2003, and begin metering traffic in May 2003. The remainder of the controllers should begin training shortly after the cadre completed their training.

Even though ZTL has not yet started to meter traffic using TMA, the TMU is using the tool to help manage ATL arrivals. In the June 2002 Metrics Report [3] we described how the TMU was using the TMA Departure Scheduler to schedule the departures of aircraft bound for ATL from within ZTL, which require Center release. Another way in which TMA is being used by TMCs, which we have not previously reported on, is to help establish miles-in-trail restrictions for arrival fixes during busy arrival periods. Traffic managers at ZTL use TMA's load graph, which displays a projected delay timeline for each fix and the airport as a whole, to determine when traffic is becoming too intense and remedial action is needed. Managers will then establish a miles-in-trail restriction at the affected meter fix or fixes. Managers have reported to us that the use of TMA to establish miles-in-trail restrictions in this way has led to fewer instances of restrictions and/or less severe restrictions. As a consequence, they have observed less holding of aircraft arriving at ATL.

In order to confirm this observation, we obtained holding logs from the ZTL TMU for the summers of 2000 and 2002. We elected to exclude the summer of 2001 from this analysis, since TMA had just become widely used within the TMU and because traffic levels in 2000 more closely match those of 2002.[3] A comparison of arrival holding for June and July, the two busiest traffic months, is presented in Table 3-3. As the table indicates, there was a substantial decrease in the number of aircraft held in 2002, although the holding delay per aircraft held was greater. However, the total holding time (i.e., the number of aircraft held times the holding delay per aircraft held) was reduced by about 24 percent.

Table 3-3. ATL Holding Comparison

	June-July 2000	June-July 2002
Aircraft Held	4,056	2,539
Mean Holding Time per A/C Held	17.6 min	21.5 min
Total Holding Time	1,191 hr	909 hr

[3] According to ASPM, during June and July there were a total of 73,256, 76,229, and 73,020 scheduled arrivals to ATL in 2000, 2001, and 2002, respectively.

Admittedly, all of this reduction in holding may not have resulted from TMA usage in the ZTL TMU. Delta Airlines, the major air carrier at ATL, had adjusted its schedule between 2000 and 2002. Figure 3-7 shows the total counts of scheduled arrivals at ATL in 15 minute intervals for June through July, 2000 and 2002. While the total number of scheduled arrivals is about the same, Delta apparently increased the number of arrival peaks from 9 to 11, reducing the height of most of these peaks. One would expect the resultant reduction in intensity of arrival flows to lead to a corresponding reduction in circular holding.

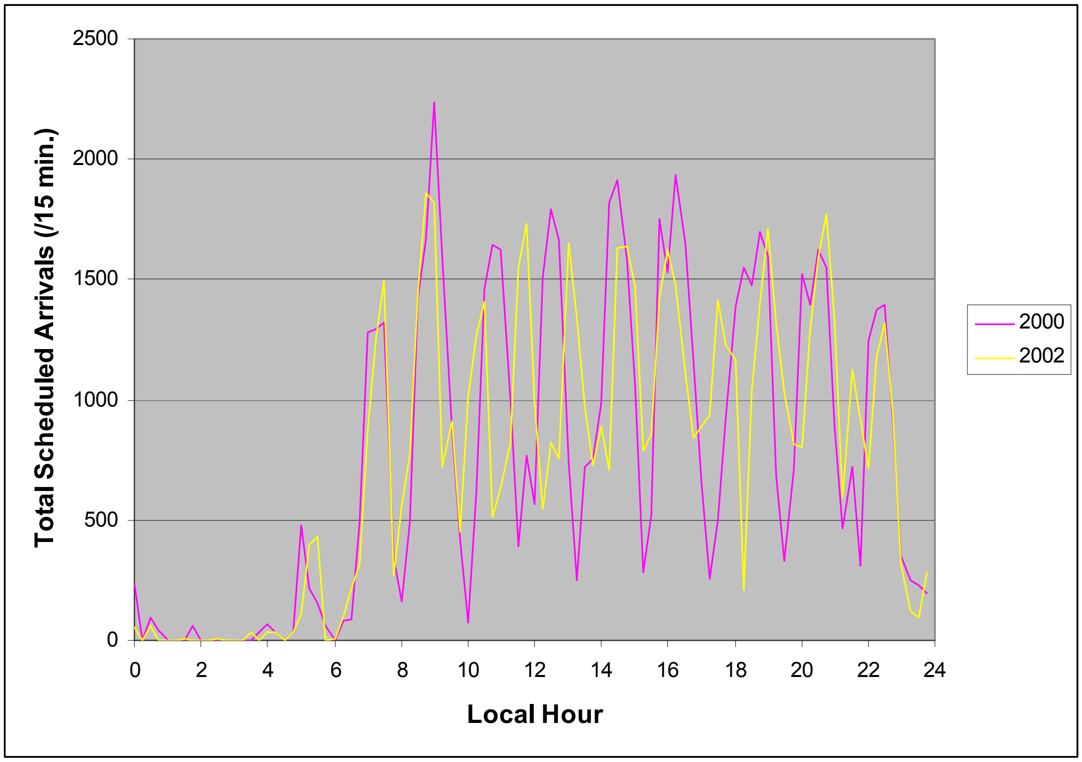


Figure 3-7. ATL Scheduled Arrivals, June and July 2000 vs. 2002

3.5 TMA at ZOA/SFO

TMA became operational at ZOA for SFO arrivals on 31 August 2001. As at Atlanta Center, Oakland Center has not yet implemented time-based metering. Nevertheless, ZOA traffic managers are using TMA to help manage flows into SFO. Specifically, TMA is being used to:

- Provide earlier, more accurate estimates of anticipated delays into SFO. The information provided by ETMS is felt by facility TMCs to be more difficult to interpret and less timely.
- Aid in a more efficient transition from in-trail operations to specific gate holding. Also better transition from holding at one gate to holding at another, based on real-time delay estimates from TMA.
- Better record-keeping of reportable and non-reportable delays.

- Better communications between the TMU and the Control Room.
- Better communications with Bay TRACON, since the TRACON also has TMA displays.
- Determine when the AAR is being exceeded by using the Scheduled Time of Arrival (STA) and Estimated Time of Arrival (ETA) timelines and delay graphs.

TMCs at ZOA report that by using TMA in these manners, they are able to apply flow restrictions earlier and further from the airport (from 100 to 125 nmi. out). This means that delays and spacing are now being performed at higher altitudes, which saves fuel and makes for a smoother flow into the airport.

In order to confirm these observations, we have examined flight times and distances for SFO arrivals, and delays for arrivals that originate at airports whose departures are controlled by ZOA.

3.5.1 Flight Distance Analysis

We analyzed flight track data to see if there has been a change in distance flown for SFO arrivals following TMA adoption. We have also included a measure of TRACON flight times from two meter fixes although, as mentioned earlier, flight times are highly dependent on wind speeds, which is difficult to statistically control for in terminal or transition airspace. For this analysis the flight paths of arriving aircraft were segmented by various range rings centered on SFO. The rings used are:

- Outer Arc (OA) at 145 nmi
- Inner Arc (IA) at 90 nmi
- Meter Arc (MA) at 40 nmi.

Figure 3-8 shows a simple map of Northern California with the outline of the Bay TRACON, as well as the placement of the range rings. Host data was used for the calculation of average flying distances between the various range rings. We chose the July to August period of 2001 and 2002 for this comparison. The summer months tend to have the highest traffic levels, and by limiting the data to this period we have avoided the difficulties of using data around September 2001. Additionally, we have limited the data set to those aircraft arriving between 9:30 and 10:15 local time, and 18:15 to 19:45 local time. A demand comparison using ASPM indicates that these time periods are fairly well matched between 2001 and 2002.

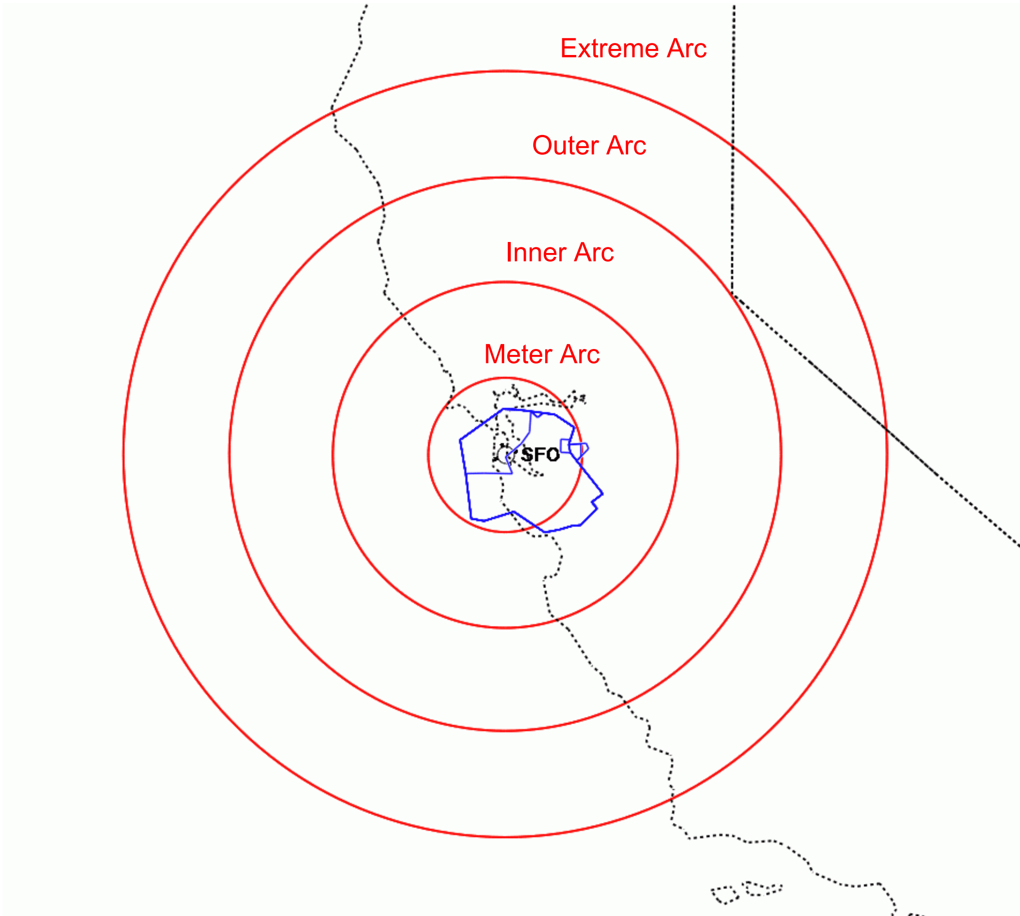


Figure 3-8. SFO Range Rings for Flight Distance Metrics

Figure 3-9 presents a comparison of mean flight distances for SFO arrivals for the two periods examined. The figure also presents 95 percent confidence intervals about the means. There was a slight increase in flight distance from the Outer Arc to the Inner Arc, but a significant decrease from the Inner Arc to the Meter Arc. Overall there has been a reduction in flight distance of approximately 2.5 nmi since TMA introduction.

Figure 3-10 presents the standard deviation of these flight distances. Note that there was a very small increase in the standard deviation from the Outer Arc to the Inner Arc, but a substantial decrease from the Inner Arc to the Meter Arc. Thus flight distances for SFO arrivals have become much more predictable since TMA adoption.

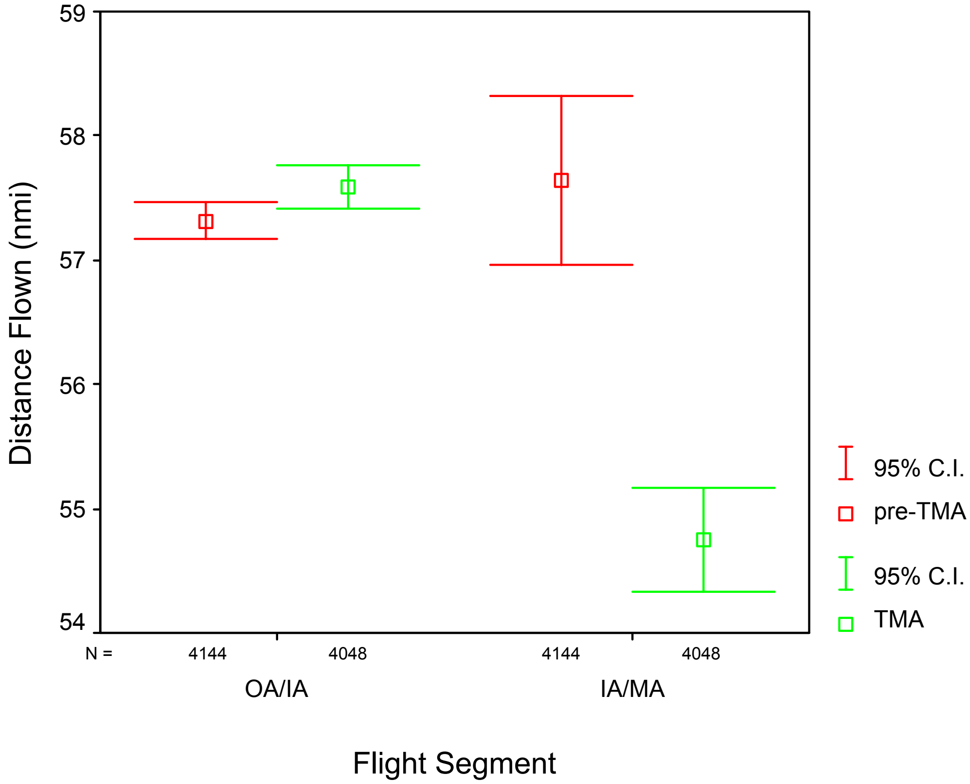


Figure 3-9. SFO Arrival Flight Distance Comparison

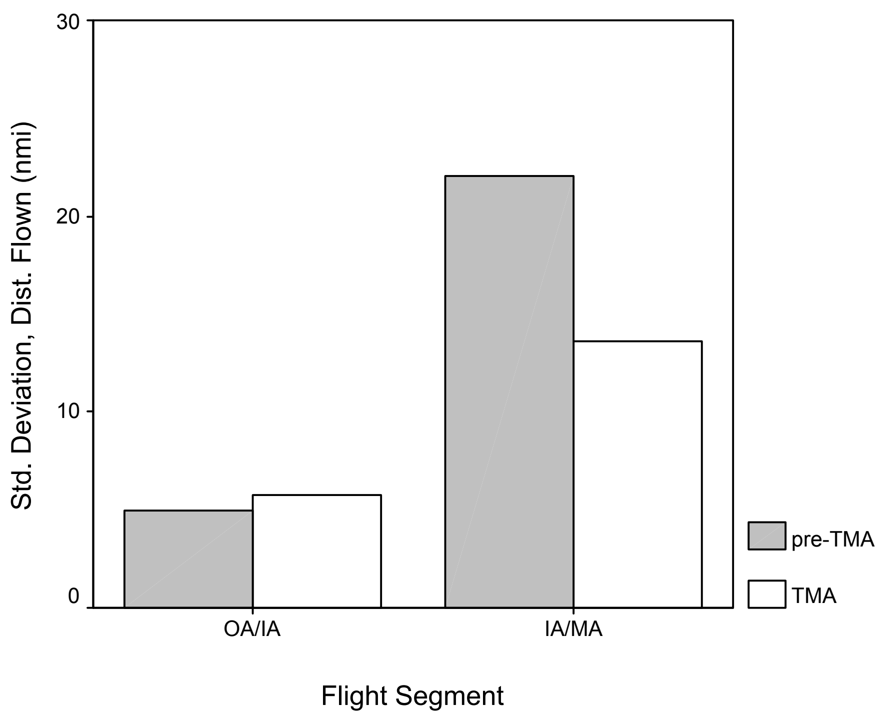
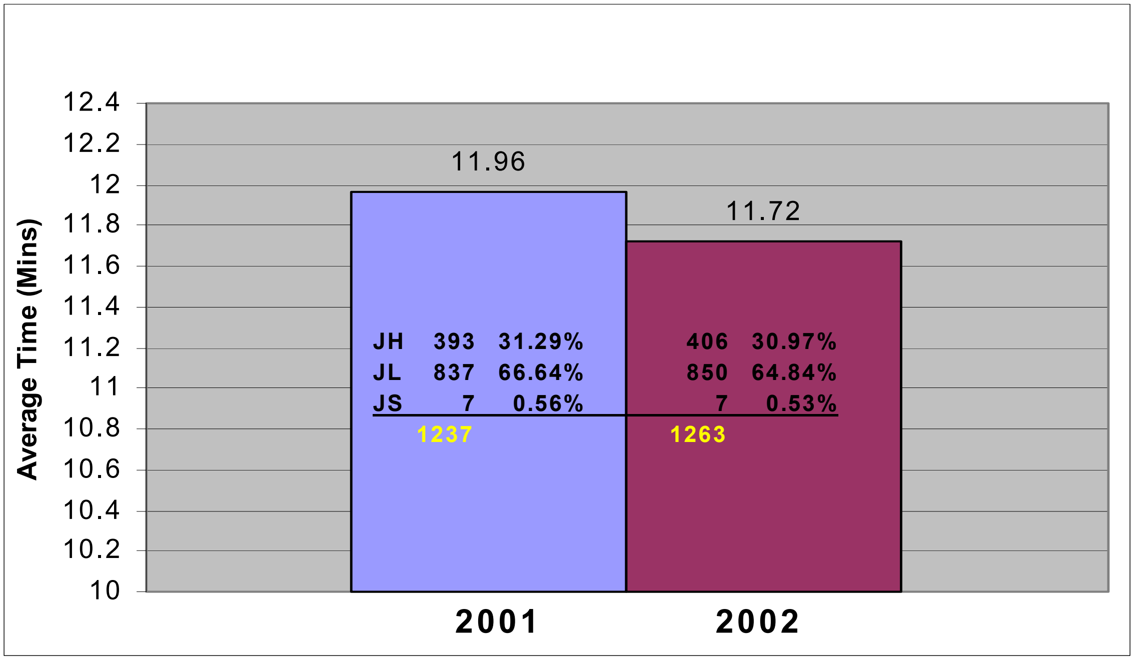


Figure 3-10. SFO Arrival Flight Distance Comparison, Standard

3.5.2 Flight Time Analysis

In addition to an investigation of flight distances outside the TRACON, we also analyzed flight times within SFO TRACON (flight track data for evaluation of distance was not available). Fig 3-11 shows average time in SFO TRACON as measured from the Meter Arc (MA) to threshold utilizing the meter fixes (or corner posts) CEDES and SKUNK. These two fixes accounted for 78 percent of the total arrival traffic in 2001 and 68



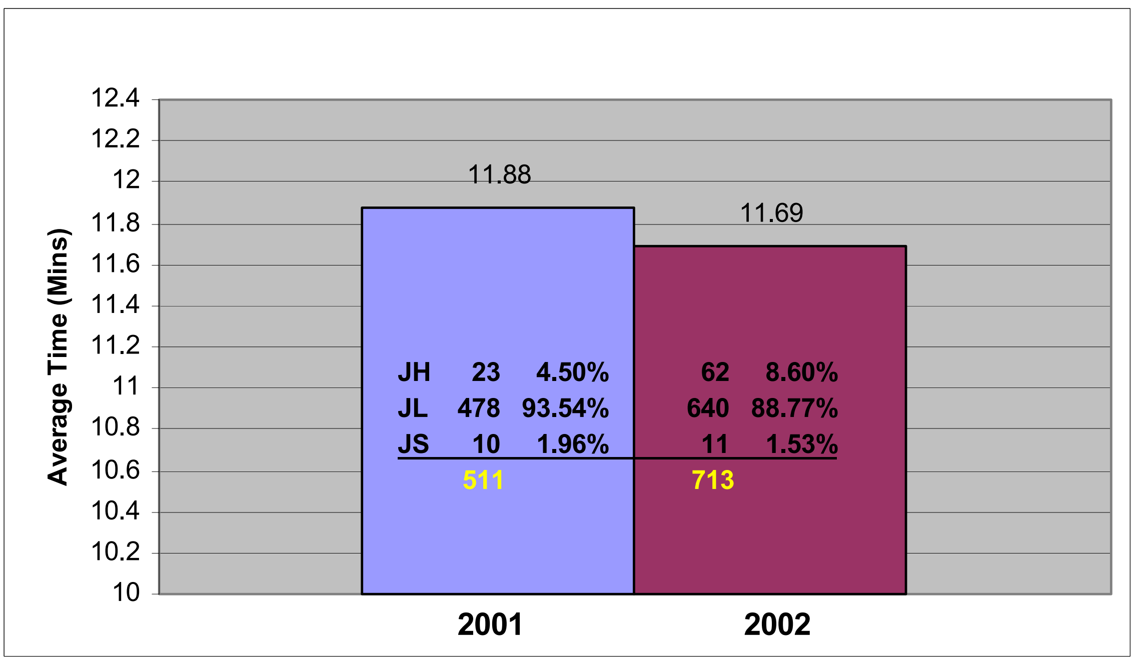


Figure 3-11. SFO TRACON Flight Times July-August 2001/2002.
Top: CEDES Post; Bottom: SKUNK Post

percent in 2002. Using data from ASPM and Host flight tracks, we were able to measure the flight time from these arrival fixes to the airport. Although arrivals are down at SFO overall, for this evaluation period we have seen an approximately 15 percent increase, thereby assuring the overall reductions in both flight distance outside the TRACON and flight time inside the TRACON are not a result of less demand. This measurement seems to bear out what we hear anecdotally from ZOA personnel. Again, there may be factors other than TMA, like wind, that have affected these flight times.

3.5.3 Internal Departure Analysis

We also examined the gate and airborne delays for aircraft arriving at SFO that departed from airports that are released by ZOA. We collected delay data from the ASPM system for the following airports:

- CIC – Chico
- FAT – Fresno
- MOD – Modesto
- MRY – Monterey
- RDD – Redding
- RNO – Reno
- SMF – Sacramento.

The baseline period for this analysis was September 2000 through August 2001, the twelve months prior to IDU at ZOA. The TMA in-use period was December 2001 through November 2002, the most recent 12 months available. Thus the period just around September 2001 has been removed from the data set.

Average airborne and gate delays for these time periods are summarized in Figure 3-12. There has been a significant reduction in both gate and airborne delays for these internal departures since the introduction of TMA.

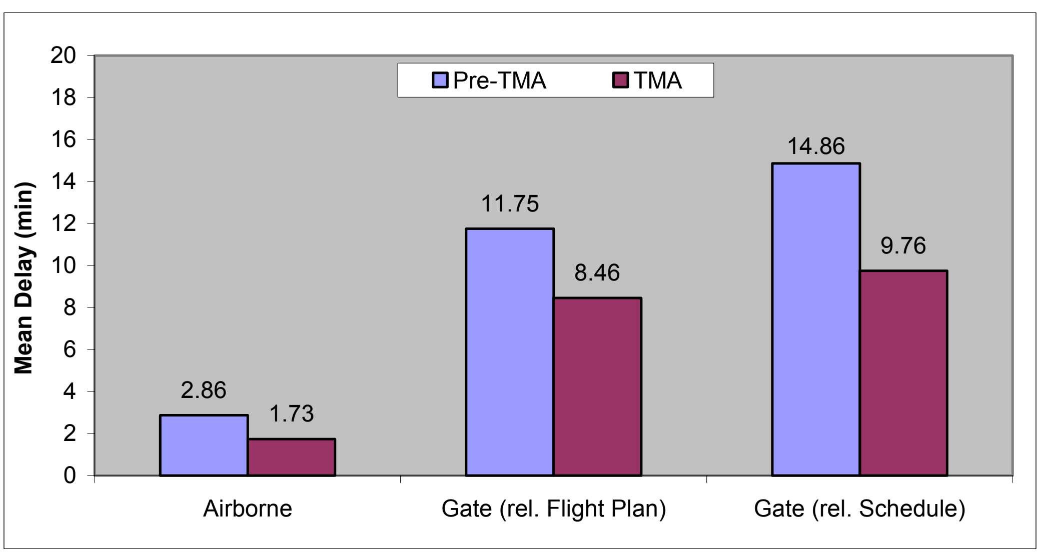


Figure 3-12. SFO Internal Departure Airborne and Gate Delays

3.6 TMA at ZMA/MIA

TMA became operational at ZMA for MIA arrivals in May 2001. As at the other Centers featured in this report, ZMA has not yet fully implemented time-based metering. Nevertheless, the TMU is using TMA as an aid in their decision making. The tool is currently used daily between 6:00 and 22:00 local time by the TMU. Meanwhile, a cadre of controllers has completed DYSIM training in time-based metering, and is scheduled to begin using time-based metering operationally in January 2003. TMA displays are also operational at the MIA TRACON, where the TMU uses the system's load graph to help make decisions about airport configuration, restrictions, and staffing.

3.6.1 Flight Distance Analysis

As was done for LAX, we examined the flight distances for MIA arrivals from the Outer Arc to the Meter Arc. Figure 3-13 depicts the range rings used for MIA analyses. The distances from the airport are as follows:

- Outer Arc – 180 nmi.
- Inner Arc – 110 nmi.
- Meter Arc – 40 nmi.

We compared the mean flight distances between these range rings, before and after TMA adoption at ZMA. For the before TMA period we used January through March 2001, and for the after TMA period January through March 2002. There has been a significant decrease in traffic at MIA since early 2001 (approximately 13 percent). In order to ensure comparability, we focused exclusively on the time period from 11:30 to 13:00 local time (the noon rush). Arrival demand is essentially unchanged during this rush between the two years (see Figure 3-14).

The mean flight distances between these range rings, and 95 percent confidence intervals about these means, are presented in Figure 3-15. There was a significant decrease in flight distances from the Outer Arc to the Meter Arc between these periods. The mean distance decreased from 155.1 to 149.1 nmi., or 6 nmi. There were corresponding decreases between the Outer Arc and Inner Arc, and the Inner Arc and Meter Arc.

We also examined the variation of flight distances between these arcs for the two time periods. Figure 3-16 presents a comparison of the standard deviation of the flight distances for the various flight segments, before and after TMA introduction. There has been a substantial reduction in the variation of flight distances for all of the flight segments examined.

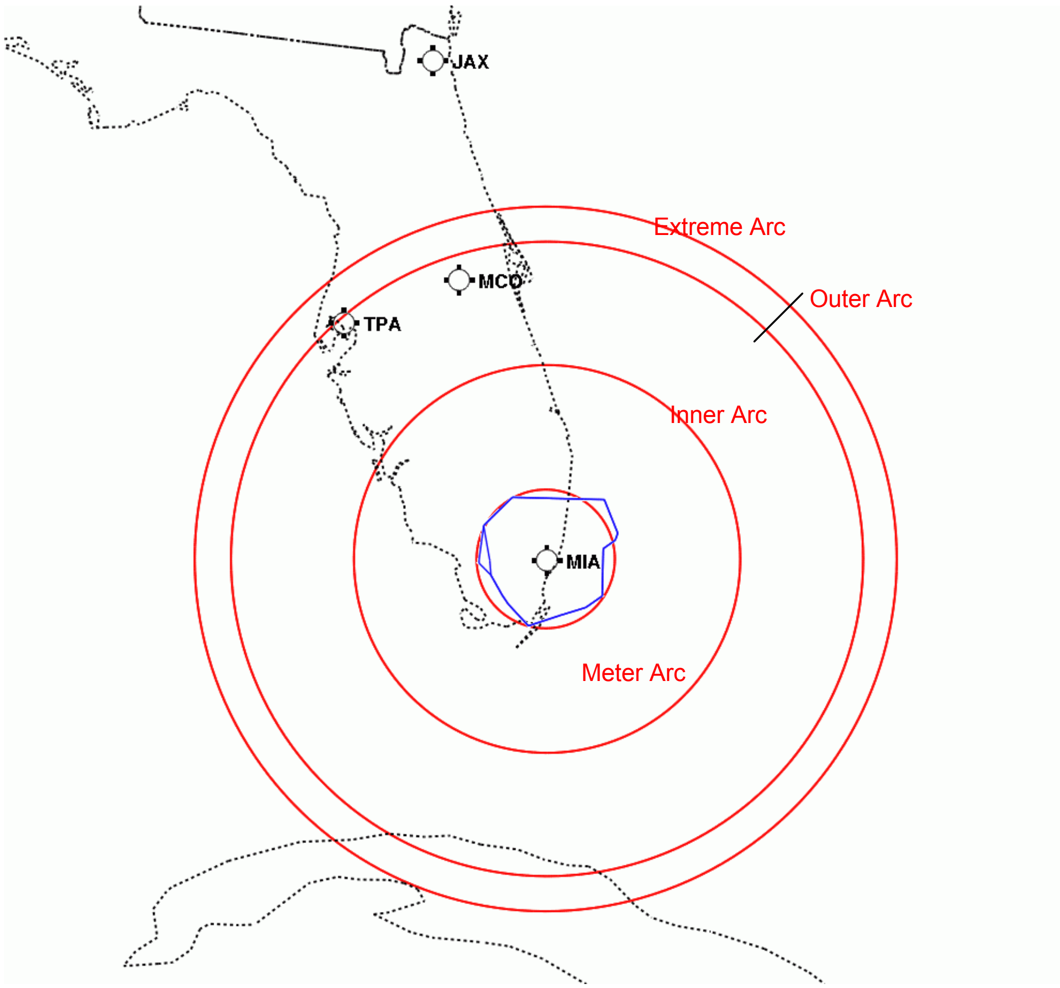
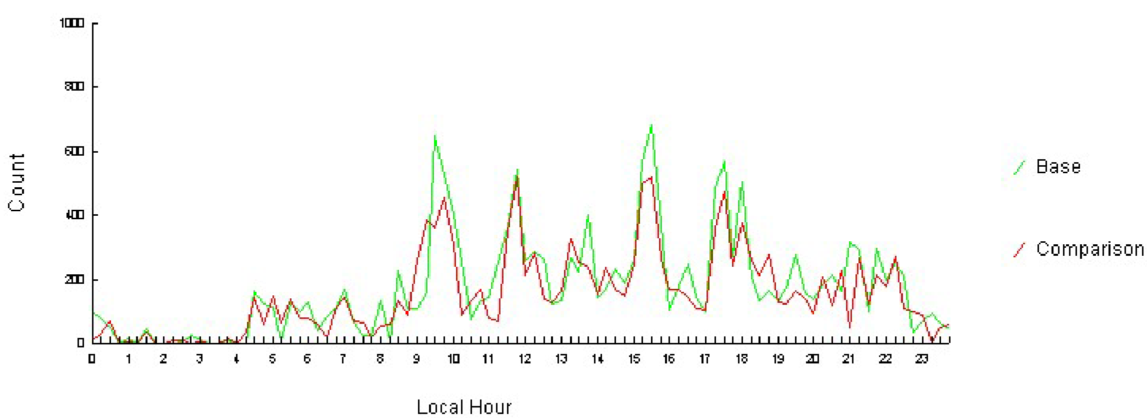


Figure 3-13. MIA Range Rings for Flight Distance Metrics



Base Period: Jan. 2001 Comparison Period: Jan. 2002

Figure 3-14. MIA Arrival Demand Comparison

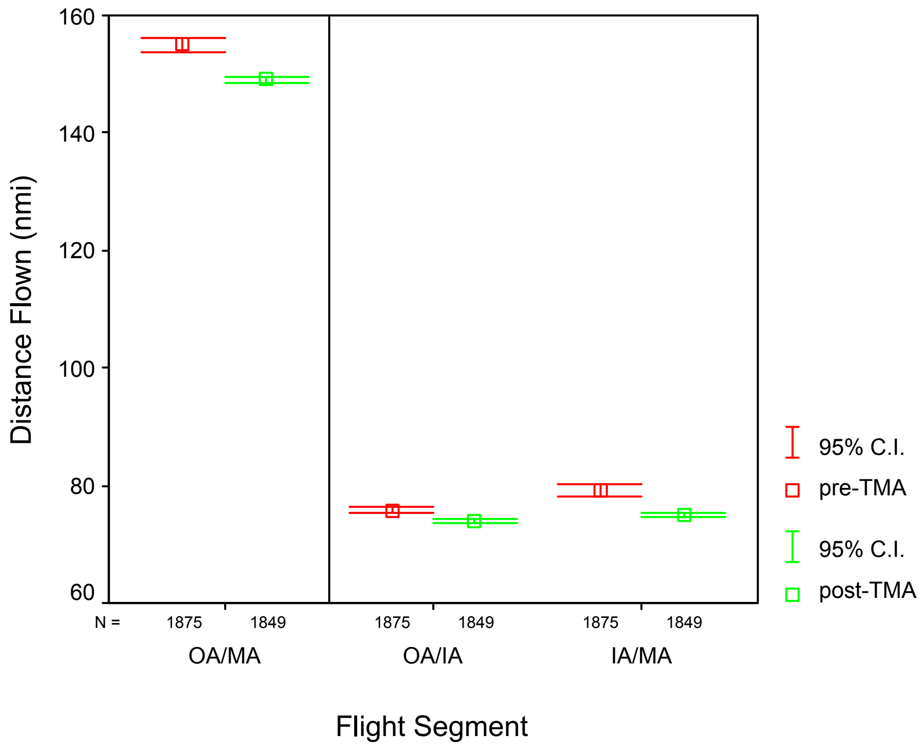


Figure 3-15. MIA Arrival Flight Distance Comparison, OA to MA

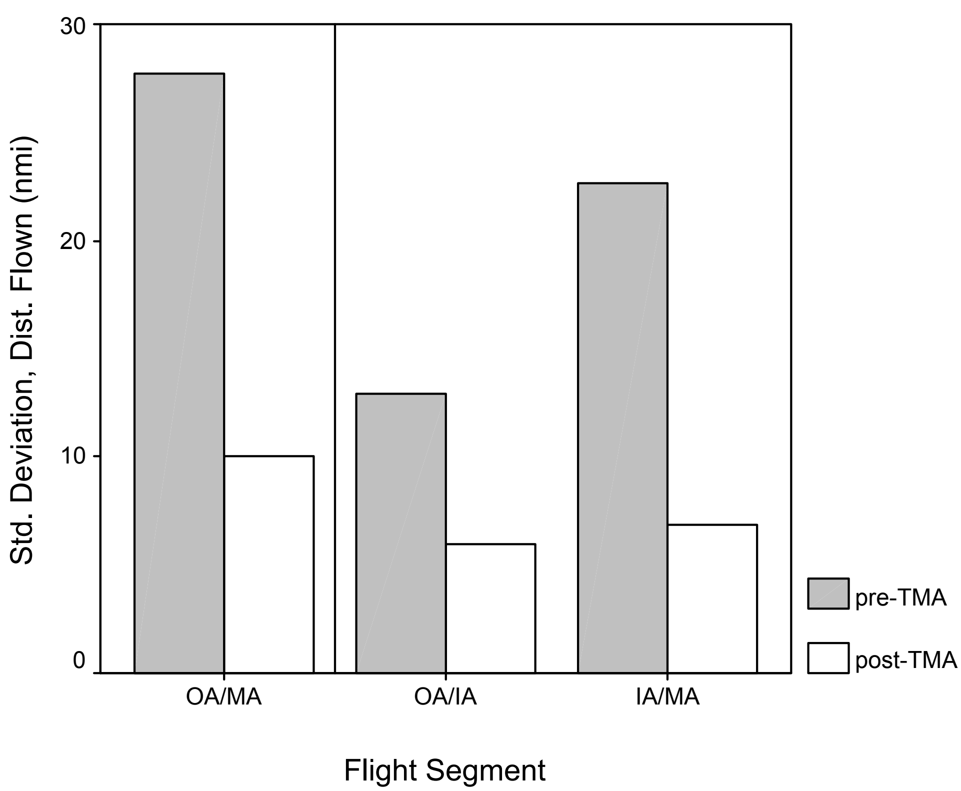
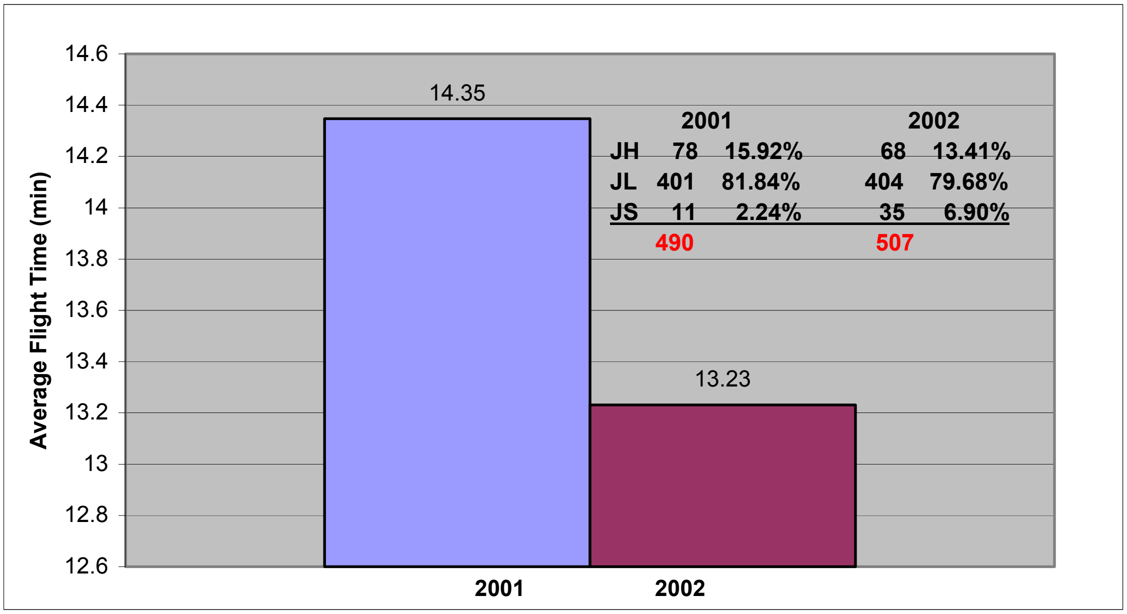


Figure 3-16. MIA Arrival Flight Distance Comparison, OA to MA, Standard Deviation

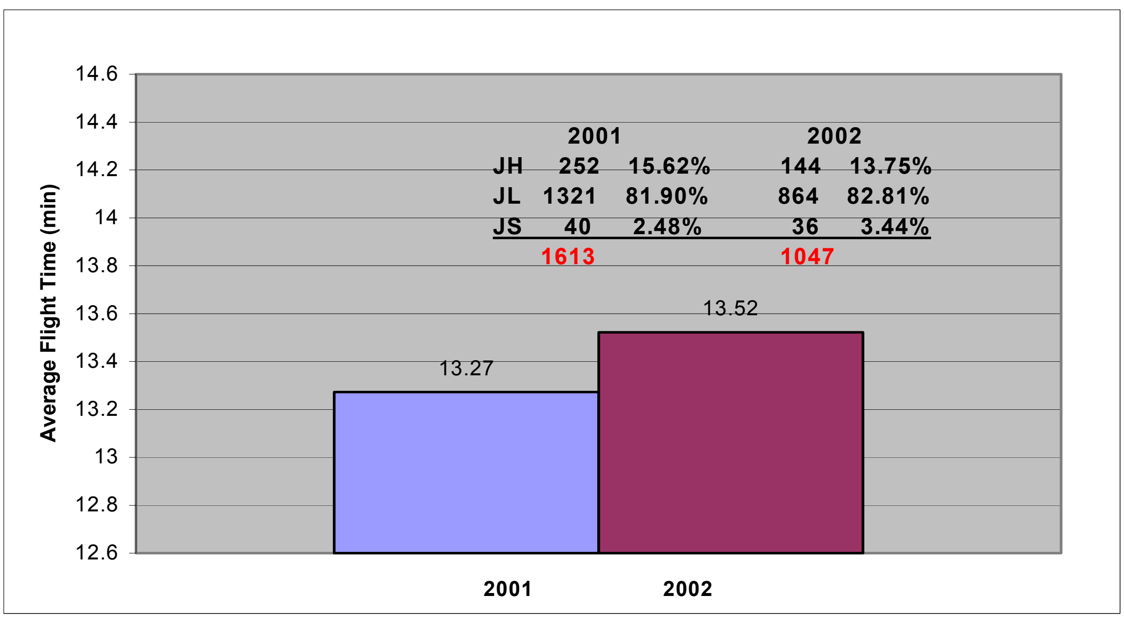
3.6.2 Flight Time Analysis

We also compared flight times from the meter fix to the runway to determine if any of the flight time reductions outside the meter arc were being moved down stream to the TRACON. Flight times were used instead of flight distance because we did not have access to track data for MIA during the study period. We considered flight times for jets only to remove the effect of year to year changes in fleet mix (specifically, the reduction in the numbers of turboprops), which can distort flight time trends. Flight times for MIA



Jan.-March, 11:00 to 14:00 Local Time

Figure 3-17. MIA Arrival Flight Time Comparison, MA to Runway, East Configuration



Jan.-March, 11:00 to 14:00 Local Time

Figure 3-18. MIA Arrival Flight Time Comparison, MA to Runway, West Configuration

were segregated by East and West configurations and analyzed for each of the four meter fixes flowing aircraft to runways. Average flight times are summarized in Figures 3-17 and 3-18. For an east airport configuration (runways 12, 9L&R), average flight time in the TRACON have decreased since TMA introduction, and average flight times for a west airport configuration slightly increased. In total, flight times have decreased, which assured us that the savings found outside the TRACON were not lost inside the TRACON.

3.6.3 Internal Departure Analysis

The baseline period for this analysis was May 2000 through April 2001, the twelve months prior to IDU at ZMA. The TMA in-use period was December 2001 through November 2002, the most recent 12 months available. Thus the period just around September 2001 has been removed from the data set.

Average airborne and gate delays for these time periods are summarized in Figure 3-19. There has been a significant reduction in both gate and airborne delays for these internal departures since the introduction of TMA. As noted earlier, however, there has also been a significant reduction in traffic at MIA since 2000. Unlike for the previous flight distance analysis, there has been no attempt in this delay comparison to control for this difference in arrival demand.

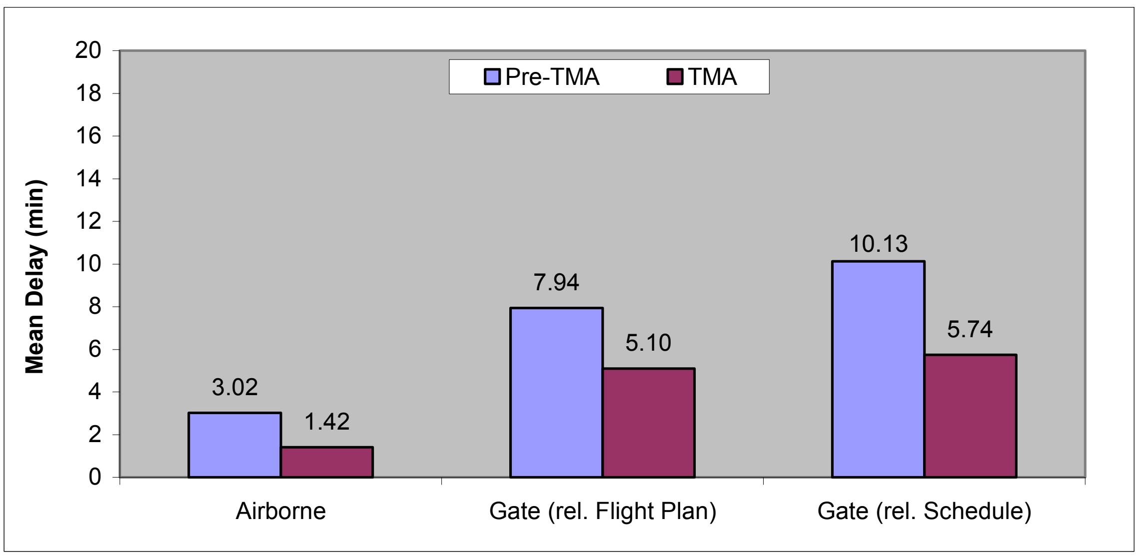


Figure 3-19. MIA Internal Departure Airborne and Gate Delays

4.0 COLLABORATIVE DECISION MAKING

Collaborative Decision Making (CDM) is a joint government/industry initiative aimed at improving air traffic management through increased information exchange, procedural changes, tool development, and common situational awareness among the various parties in the aviation community. The program is one of the core technologies in the FAA's Free Flight program and includes participants from the FAA, aviation industry, and academia.

Evaluations of CDM conducted prior to this report focused on the benefits of Ground Delay Program Enhancements (GDPE). A ground delay program (GDP) is an air traffic management initiative used to control traffic flow into an airport by delaying flights on the ground at their departure sites. The following quantifiable results were attributed to GDPE:

- increased departure compliance (for flights in a GDP)
- improved flight departure predictions (for flights in a GDP) as a result of airline input to ETMS modeling
- better GDP performance, measured by how well the actual arrival flow matched the predicted arrival flow; increased user equity, based on how arrival slots are allocated during a GDP
- increased user equity, based on how arrival slots are allocated during GDP
- minutes of delay saved by *compression*, a GDP revision feature in which flights are moved into earlier arrival slots vacated by cancelled or delayed flights.

Each year, the CDM scope is expanded as new tools or enhancements are developed and employed. Studies have been undertaken to evaluate the benefits of the latest CDM implementations, and these are included here. The initiatives evaluated for this report include the change to a five minute compliance window for Estimated Departure Clearance Times (EDCTs), the use of the Collaborative Convective Forecast Product (CCFP) (and resulting traffic patterns) on days of predicted/actual convective weather, and the use of the Post Operations Evaluation Tool (POET). Each of these CDM initiatives, as well as the results of the analyses, is described in more detail in the following sections.

4.1 +/- 5 Minute EDCT Compliance Window

4.1.1 Description/Operational Use

Every flight that is included in a GDP (or is "controlled") is assigned an EDCT, sometimes also called a Controlled Time of Departure (CTD). Previously, a window of -5/+15 minutes was allowed for a flight to meet its EDCT. As of April 2, 2002, this window was tightened so that flights must now depart within +/-5 minutes of their EDCTs.

4.1.2 Background/Definitions

Metron Aviation, Inc. (MAI) has studied the effects of this change in compliance window, and the results presented in this section are taken directly from their report [8]. The full content of the MAI report is not covered here, and the reader is referred to the original document for more details of the analysis. In this report some additions or changes have been made to the original MAI text for continuity and clarity.

The difference between the actual runway time of departure (ARTD) and the CTD at departure time (DepartCTD) is used to evaluate the *departure compliance* of each flight. A flight is considered to be *compliant* if the difference between ARTD and DepartCTD is between –5 and +5 minutes.

Arrival compliance is defined by the difference between the actual runway time of arrival (ARTA) and the control time of arrival (CTA) for a flight. Because the CTA of an exempt flight is subject to fluctuation, even after takeoff, the CTA at departure (DepartCTA) is used for calculating arrival compliance.

Baseline (or *base*) data consisted of controlled flights from January 1, 2001, through April 1, 2002, before the window reduction. The timeframe for the baseline period was somewhat arbitrary, but was chosen to ensure selection of a year's worth of data, including data to permit an April 2001 to April 2002 comparison. The *test* data set contained data on flights between April 2 and April 30, 2002. In addition, flights bound for seven specific airports during GDPs were exempt from all en route restrictions such as miles-in-trail (MIT) and enroute spacing (ESP). These seven airports were ATL, DTW, EWR, ORD, PHL, SFO, and STL.

4.1.3 Results

4.1.3.1 Departure Compliance

Figure 4-1 shows the departure compliance distribution for all GDP flights for both time periods. Because the sample sizes for the two groups were so different in magnitude, the frequency distributions were normalized by the sample counts to give a percentage of all departures with a specific compliance. The baseline and test data sets contained 194,911 and 11,541 flights, respectively. The most frequently observed value of departure compliance in both data sets was negative four minutes (i.e., four minutes early). Baseline flights had an average departure compliance of 2.4 minutes; for test flights, the average decreased to 1.4 minutes. The standard deviation was reduced from 32.1 to 25.0 minutes.

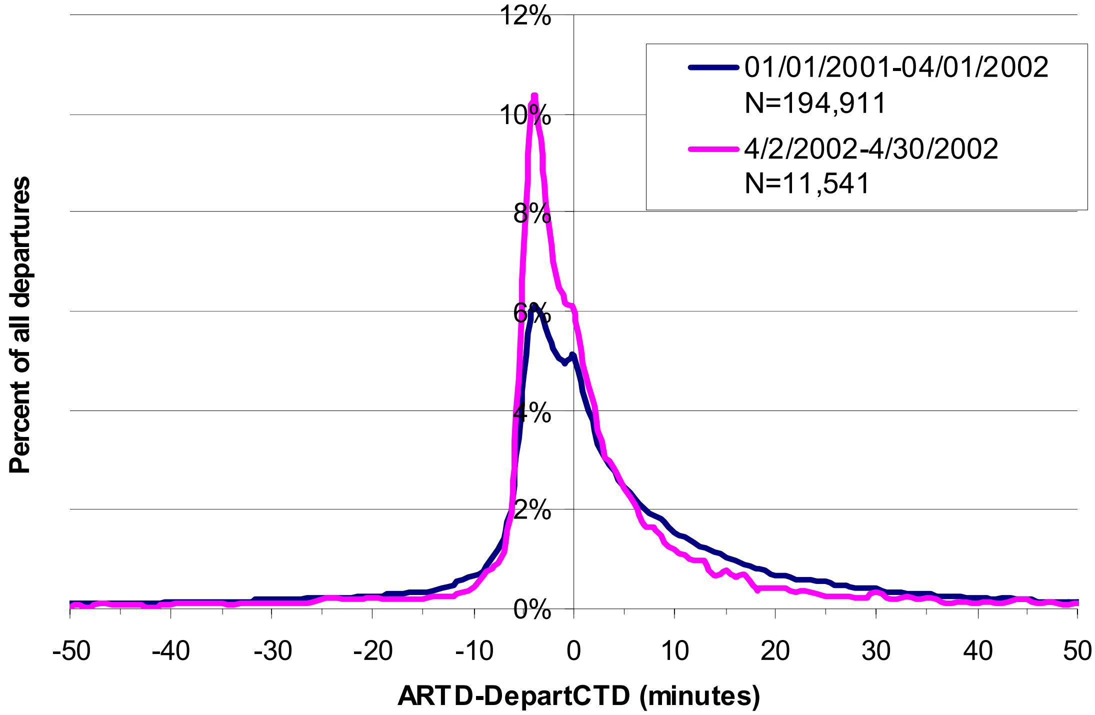


Figure 4-1. Normalized Frequency Distribution of Departure Compliance

Because the standard deviation can be sensitive to outlying values, a "trimmed" average absolute error (AAE) was also calculated, where values of departure compliance that exceeded 360 minutes were excluded. Absolute error is the magnitude of the difference between a flight's ARTD and its CTD. A flight departing 10 minutes early and a flight departing 10 minutes late would have an average departure compliance of zero minutes (the average of –10 and +10), while the AAE for the two flights would be 10 minutes (the average of |-10| and |+10|). The AAE for the baseline data is 16.3 minutes; in the test data, this drops to 11.6 minutes.

Flights to the seven test airports demonstrated greater improvement in departure compliance than the average departure compliance for non-test airports. MAI analysts attribute this increased level of improvement to the greater attention placed on GDPs at these seven airports during the test. The lifting of restrictions also may have contributed to improvements in departure compliance of flights destined for one of the test airports. The results of the departure compliance test for all GDP flights and for the seven test airports are summarized in Table 4-1.

Table 4-1 Summary of Departure Compliance Results

Flights destined to:	# GDPs		count		mean		stdev		Change in stdev	Avg Abs Err		Change in AAE
	Base	Test	Base	Test	Base	Test	Base	Test		Base	Test	
seven test aiports	538	40	131,705	10,136	2.1	0.9	31.4	23.3	-8.1	15.9	10.6	-5.3
non-test airports	427	13	63,206	1,405	3.1	5.2	33.6	34.8	1.2	17.3	18.7	1.5
all airports	965	53	194,911	11,541	2.4	1.4	32.1	25.0	-7.1	16.3	11.6	-4.7

Table 4-2 presents the departure compliance results by departure airport. The largest reduction in standard deviation and AAE occurred at EWR. The reduction of 8.1 minutes in AAE for EWR indicates that flights departing from EWR during the test were on average 8.1 minutes closer to their DepartCTD. Flights departing from STL were missing their DepartCTD by 2.5 minutes more than before the test began. These results have not been statistically verified due to the small sample sizes being analyzed.

Table 4-2. Departure Compliance Results by Origin Airport

Rank	Origin	Count		Mean		StDev		Change in StDev	Avg Abs Err		Change in AAE
		Base	Test	Base	Test	Base	Test		Base	Test	
1	DFW	5326	303	2.1	0.2	26.9	23.7	-3.2	13.1	11.2	-1.8
2	ORD	5989	302	2.0	-1.0	29.8	28.2	-1.6	15.9	15.4	-0.5
3	LAX	3737	277	3.2	1.1	27.7	17.8	-9.9	13.3	8.3	-5.0
4	BOS	4686	263	10.4	3.2	33.9	30.0	-3.8	19.5	13.0	-6.6
5	DEN	4422	261	5.6	0.1	28.3	15.3	-13.0	13.9	6.6	-7.3
6	ATL	4911	242	4.0	3.1	26.7	24.8	-1.9	14.6	12.4	-2.2
10	EWR	3167	198	1.9	0.0	31.0	16.4	-14.5	17.1	9.1	-8.1
11	PHL	2944	196	4.7	5.1	33.2	34.6	1.3	18.6	17.0	-1.6
12	DTW	3272	195	3.4	3.6	29.2	26.2	-2.9	16.8	14.0	-2.8
22	STL	2782	159	1.7	9.1	25.0	31.5	6.5	12.9	15.4	2.5
36	SFO	2724	112	5.0	-1.4	25.4	18.3	-7.1	13.2	8.6	-4.6

Seven Test Airports:

4.1.3.2 Arrival Compliance

MAI analysts also examined GDP arrival compliance during the test. The largest reduction in standard deviation and AAE was realized at the seven test airports (Table 4-3). Non-test airports also demonstrated a small reduction in standard deviation yet an increase in AAE. The third row of Table 4-3 shows that, on average, the standard deviation and AAE were reduced by 6.2 minutes and 3.9 minutes, respectively, for all GDP flights during the test.

Table 4-3. Summary of Arrival Compliance Results

Metric: (ARTA - CTA)	Count Base	Count Test	Mean Base	Mean Test	Stdev Base	Stdev Test	Change in Stdev	Avg Abs Error Base	Avg Abs Error Test	Change In AAE
seven test airports:	96,562	7,519	1.0	1.1	29.2	23.1	-6.1	16.0	12.1	-3.9
non-test airports:	47,701	890	-0.3	0.7	32.2	31.2	-1.0	17.9	18.1	0.2
all airports:	144,263	8,409	0.6	1.0	30.2	24.0	-6.2	16.7	12.8	-3.9

The small values of standard deviation and average absolute error for the seven test airports indicate that GDP arrivals were more predictable at these airports than at the non-test airports.

4.1.3.3 Arrival Predictability

Table 4-4 shows the correlation between departure compliance and arrival compliance for all GDP flights that arrived during programs in the baseline and test samples. The shaded column in each table shows the categories of departure compliance. The most notable result is that the percentage of on-time departures increases from 49 percent to 64 percent between the baseline and test periods. The shaded row shows overall arrival compliance, and this increases from 27 percent to 35 percent. Reading across each row shows the breakdown of arrival compliance within each category of departure compliance. For example, of the 49 percent of flights in the baseline sample that departed on-time: 27 percent arrived early, 42 percent arrived on-time, and 31 percent arrived late. The breakdown shows that a flight is far more likely to arrive on time if it departs on time.

Table 4-4. Arrival Predictability for all GDP Flights in the Base and Test Samples

BASE
N=144,291

Departure \ Arrival	%	Early	On-Time	Late
%		30	27	43
Early	19	79	14	7
On-Time	49	27	42	31
Late	33	6	13	81

TEST
N=8,411

Departure \ Arrival	%	Early	On-Time	Late
%		26	35	39
Early	14	73	19	8
On-Time	64	24	46	31
Late	22	5	15	80

"Early" corresponds to (-360, -6) minutes, "On-Time" = (-5, +5) minutes, "Late" = (6, 360) minutes.

4.1.4 Summary and Conclusions

Departure Compliance

- Comparing all controlled departures during the test period to those in the baseline period, we see a 15 percent improvement in departure compliance. That is, the percentage of flights departing within plus-or-minus five minutes of assigned CTD increased by 15 percent. The mean departure compliance decreased by one minute, the standard deviation decreased by 7.1 minutes, and the average absolute error by 4.7 minutes.

- Averaging over the seven airports that were the focus of the test, departure compliance improved by 16 percent. The average decreased by 1.2 minutes, the standard deviation decreased by 8.1 minutes, and the average absolute error by 5.3 minutes. In contrast, controlled departures for all destinations (other than the seven test airports) did not have an overall improvement in departure compliance: the mean value increased by 2.1 minutes, the standard deviation increased by 1.2 minutes, and the average absolute error increased by 1.5 minutes.
- The improvement in standard deviation is noteworthy because it is a measure of predictability. A large standard deviation implies wide variation from the mean within the sample; small standard deviation implies less variation from the mean, hence more predictability.

Arrival Compliance

- The seven test airports showed an 18 percent decrease in standard deviation and a 23 percent improvement in the AAE of arrival compliance. The standard deviation and average absolute average error did not change significantly for non-test airports. However, improvements in arrival predictability occurred not only for the seven test airports, but also for the entire population of controlled flights during the test.
- There was strong positive correlation between on-time departure compliance and arrival compliance. A flight was approximately twice as likely to arrive within +/- 5-minutes of its CTA if it was departure compliant. Improved arrival compliance is a measure of increased predictability in the NAS. However, the increased arrival compliance may be influenced by the lifting of restrictions for the seven test airports during the test period, rather than solely due to the enforcement of the new +/- 5 minute window.

4.2 POET

4.2.1 Description

The Post Operations Evaluation Tool (POET) is a prototype analysis system developed by MAI, Cognitive Systems Engineering, and AMT Systems Engineering under the FAA's CDM program. POET is designed to support the analysis of collaborative routing problems and the identification of areas of NAS congestion or inefficiency. POET allows users to explore how the NAS functions using a variety of performance metrics, including departure, en route, and arrival delays and filed versus actually flown flight tracks.

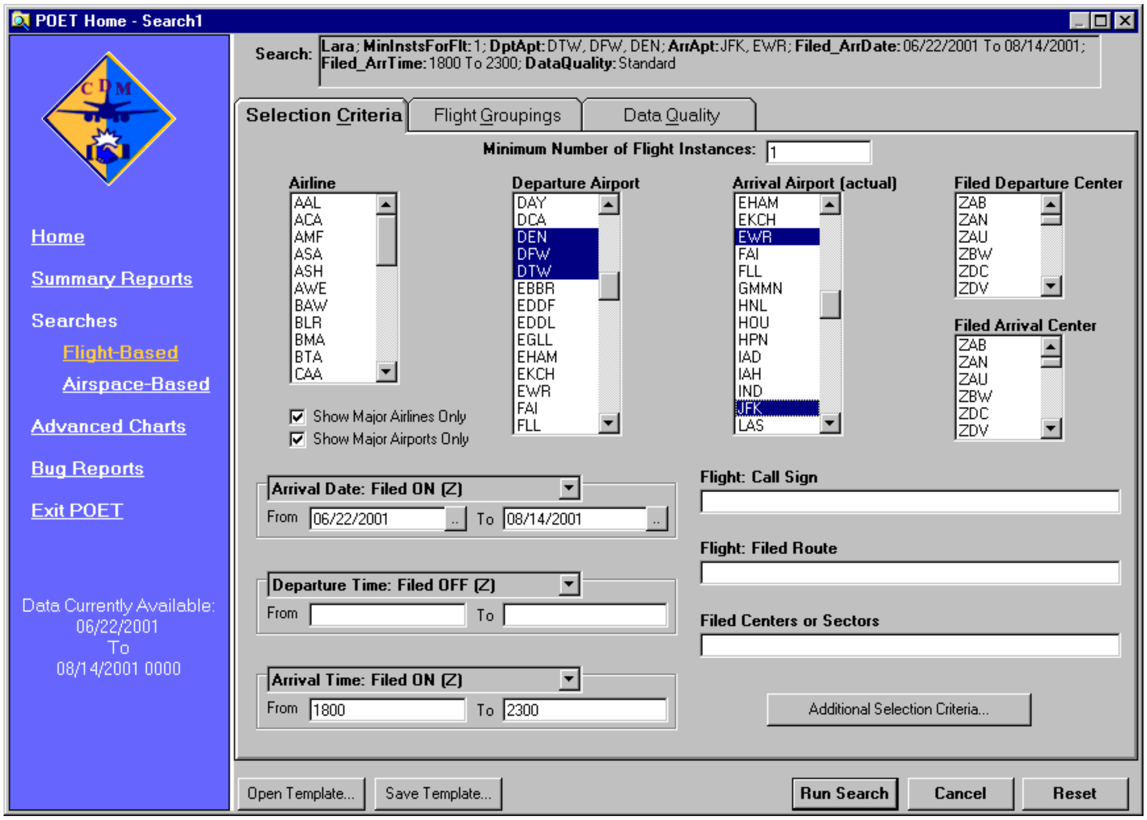


Figure 4-2. POET Query Graphical User Interface

The POET server maintains a "rolling" set of Enhanced Traffic Management System (ETMS) data, from the current day to 37 days prior. Users can easily access, filter, and visualize the flight information contained in the data archive using a variety of interactive charts, tables, and geographic displays. Data can be aggregated into a variety of bins including grouping by departure and/or arrival airports, filed arrival fixes, departure/arrival times, National Route Program (NRP)/non-NRP, departure and/or arrival centers, user class, and many more.

Additionally, POET includes a collection of powerful data mining tools to assist the user in recognizing patterns and trends within the data. Some of the patterns currently recognized include circular airborne holding, arrival fix swaps, and flown routes that differ significantly from the routes filed. POET has the further capability to integrate FAA data with airline-provided flight data (such as predicted and actual fuel consumption), to give a more complete picture of what is happening in the NAS.

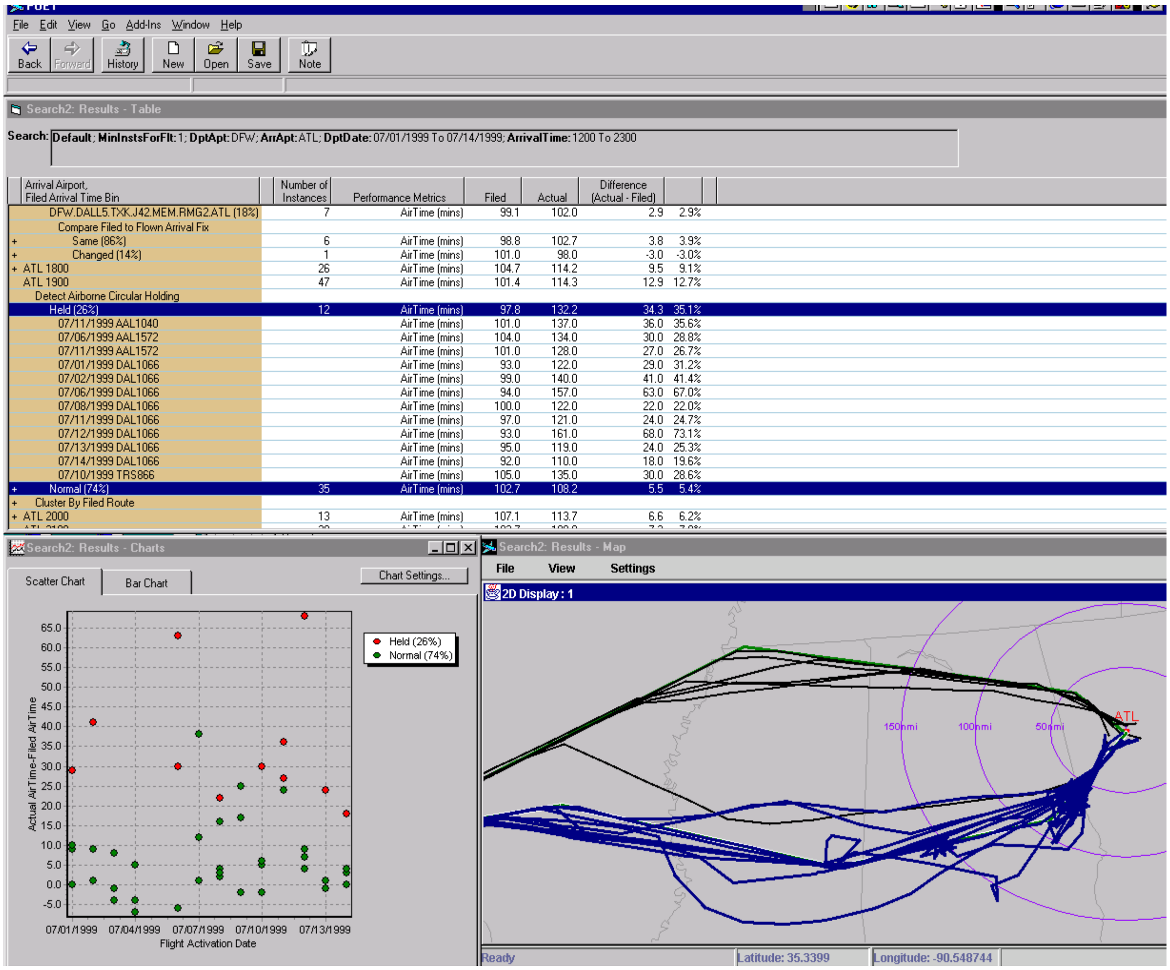


Figure 4-3. POET Display Formats — Table, Chart, and Map/Flight Replay

4.2.2 Operational Use

POET users are classified by MAI into four types, based on the results of the user survey: FAA at the ATCSCC; FAA outside the ATCSCC (for example, at ARTCCs); airlines; and others, including academia. Users described a number of air traffic analyses for which they used POET. A sampling includes: analysis of arrival/departure traffic at various airports (including delays, rates, and fix loading), identification of reroutes during SWAP, estimation of sector loading, and identification of fixes where holding occurred.

The purpose of these analyses depends on the user. For example, certain FAA operational facilities have been using POET to obtain data to support the development of multi-center TMA and *FutureFlightCenter*, two NASA-developed ATM tools. Airlines, on the other hand, use POET for route, market, and fight planning analyses. Several survey respondents at ARTCCs report preparing analyses for management, to answer information requests from NATCA, and for handling inquiries and complaints.

4.2.3 Results

Not all POET users have responded to the latest user survey. Additionally, the reply format is quite unstructured. As a result, most of the feedback on the use of POET is in the form of anecdotal reporting, as described in the above section on operational use. As of October 15, 2002, POET had 109 users on 93 workstations, with responses from more users expected in the future. The frequency of use varies widely; some use it daily, while others use it only monthly or even less frequently.

4.3 Collaborative Convective Forecast Product

Convective weather is a major cause of delays in the NAS. The Collaborative Convective Forecast Product (CCFP) was jointly developed by the FAA, the airlines, and the National Weather Service (NWS) as an attempt to improve forecasts of convective weather through collaboration, via the CDM process. This in turn can lead to a reduction in delays, reroutes, and cancellations as a result of convective weather.

4.3.1 Description

The CCFP begins as an initial forecast produced by the Aviation Weather Center (AWC) in Kansas City. Participating meteorologists from the airlines and from the Center Weather Service Unit (CWSU) collaborate, each contributing his own expertise, until a final forecast is produced. The ATCSCC monitors the feedback/input process and requests clarification where needed. While all stakeholders contribute their expertise to production of the CCFP, a decision about the final product is made by the AWC. In some cases a consensus is not reached among the participants. The goal of the CCFP is to predict convective activity (25 percent coverage or higher) that may impact the NAS. The CCFP is not intended to predict all thunderstorm activity.

4.3.2 Operational Use

The CCFP is generated six times a day and is designed to give a forecast two, four, and six hours in advance of convective activity. As agreed by all stakeholders, the CCFP is the forecast product used by traffic management specialists at the ATCSCC to develop the Strategic Plan of Operation (SPO), the plan for national air traffic management, during thunderstorm activity.

4.3.3 Analysis

On July 31, 2002, AvMet Applications International and MAI jointly produced a CCFP operational utility study [9]. Excerpts from this report are included here; some text from the AvMet/MAI report may have been edited or modified for continuity and clarity.

The study was developed in response to Collaborative Routing Workgroup interest in determining how much traffic should be rerouted for a particular forecast. Therefore, the primary focus of the study was to determine how many flights were rerouted, and whether these reroutes were necessary, in response to an issued CCFP. The report contains a historical reporting of flight data on days when a CCFP was issued, not a formulaic guideline to set the percentage of flights that should be rerouted. However, the

AvMet/MAI report states that such a guideline is a goal of a separate study that is currently underway.

This report also includes evaluations of CCFP utilization and effectiveness derived from interviews with traffic managers, dispatchers, and supervisors nationwide. Meetings were also conducted with representatives from Chicago, Cleveland, Dallas-Ft. Worth, and Washington ARTCCs, and United, American, and Southwest Airlines, and their input is included in these evaluations.

4.3.4 Results

4.3.4.1 Reroute Filing During Forecast Weather

For the quantitative portion of the analysis, MAI and AvMet selected four forecasts within the convective weather season from April 1, 2001, to August 31, 2001. The analysts identified all flights that actually flew through a CCFP polygon for forecast weather. They then identified all flights that flew through the same area on a "baseline" day (i.e., a similar traffic day when there was no weather or forecasted weather in the same region). By comparing the two lists, it could be determined which flights would be scheduled to fly through the area on a baseline day, and which ones did or did not traverse the area for a day/time when convective weather was forecast.

For the flights that were strategically rerouted, decision outcomes were used to evaluate the value of the reroutes. These were defined by AvMet/MAI as in Table 4-5. The use of these definitions can help determine whether air traffic management decisions made using the CCFP forecast were beneficial.

Table 4-5. Reroute Definitions and Decision Outcome

Flight Route	Reroute Decision	Decision Outcome
Filed route goes through the forecast area, Filed route is similar to flown route	No Reroute	Good
Filed route goes through the forecast area, Actual route deviates to avoid actual weather	No Reroute	Bad
Scheduled route goes through the forecast area, Filed route goes around forecast area, Actual weather exists on scheduled route, but not on filed route	Strategic Reroute	Good
Scheduled route goes through the forecast area, Filed route goes around forecast area, No actual weather exists on scheduled route	Strategic Reroute	Bad
Scheduled route goes through the forecast area, Filed route goes around forecast area, Actual weather exists on scheduled route and filed routes	Strategic Reroute	Needed to Reroute-Bad

Table 4-6 contains the classification of each of the identified flights according to the reroute decisions and decision outcomes.

Table 4-6. Outcome of Decision to Reroute

		Outcome			
		Good	***Bad***	***Needed To Reroute-Bad***	***Total***
Type of Reroute	***No Reroute***	341	340	-	681
	Strategic	56	68	65	189
	Unclear	-	-	-	53
	Total	397	408	65	923

Of the flights that were not rerouted, half of them did not have to later reroute around weather that actually developed in the forecast area. Out of the flights that were strategically rerouted, 64 percent had weather develop along their scheduled routes, indicating that the CCFP forecast saved a tactical reroute later.[4] However, some of these same flights ran into weather on their strategic reroutes which forced them to tactically reroute as well.

4.3.4.2 Qualitative Results

- The FAA is more likely to implement pre-emptive reroutes for forecast weather whereas the airlines prefer more tactical (reactive) implementation of reroutes, in case the weather does not develop. Therefore, despite the presence of the CCFP, it may be difficult to develop a universal, strategic plan of air traffic management and flight planning that all CDM participants can agree on.

- Participants in forecast development will usually defer to their "in-house" weather forecast, for the purposes of flight planning, if it is different from the CCFP. Unless participants agree to use the CCFP, which was created to "give all users a single centralized forecast of potentially disruptive weather," it will be impossible to develop a single strategic plan of air traffic management among all CDM participants.

- Ensuring that all personnel are trained to properly utilize CCFP should increase proper forecast utilization and participation levels.

- Both airlines and FAA personnel perceived an improvement in CCFP production efficiency and accuracy, compared to the previous year. Furthermore, all parties remain highly committed to the program.

4.3.5 Summary

While the quantitative results of the test may put in question the value of the CCFP, both airlines and the FAA remain highly committed to the program. As more personnel are trained and acceptance levels of CCFP grow, it can be expected that the benefits realized from utilizing the CCFP will only increase.

[4] A tactical reroute is defined as one done while in flight.

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ACRONYMS

AAE	Average Absolute Error
AAR	Airport Acceptance Rates
AIDS	FAA's Accident/Incident Data System
ANOVA	Analysis of Variance
ARTA	Actual Runway Time of Arrival
ARTCC	Air Route Traffic Control Center
ARTD	Actual Runway Time of Departure
ASPM	Aviation System Performance Metrics
ASRS	Aviation Safety and Reporting System
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
ATL	William B. Hartsfield Atlanta International Airport
AWC	Aviation Weather Center
CAASD	Center for Advanced Aviation System Development
CCFP	Collaborative Convective Forecast Product
CCLD	Core Capability Limited Deployment
CDM	Collaborative Decision Making
CHI	Computer Human Interface
CI	Confidence Interval
CIC	Chico Airport
CNAC	The Center for Naval Analyses Corporation
CTA	Control Time of Arrival
CTAS	Center TRACON Automation System
CTD	Controlled Time of Departure
CWSU	Center Weather Service Unit
DCTD	Departure CTD
DEN	Denver International Airport
DFW	Dallas/Ft. Worth International Airport
DU	Daily Use
EA	Extreme Arc
EDCT	Estimated Departure Clearance Times
ETA	Estimated Time of Arrival
ETMS	Enhanced Traffic Management System
EYW	Key West Airport
FAA	Federal Aviation Administration
FAA	Final Arc
FAT	Fresno Airport

FFP	Free Flight Program
FLL	Fort Lauderdale Airport
GDP	Ground Delay Program
GDPE	Ground Delay Program Enhancements
GPD	Graphic Plan Display
IDU	Initial Daily Use
IFR	Instrument Flight Rules
JH	Heavy Jet
JL	Large Jet
JS	Small Jet
LAX	Los Angeles International Airport
MA	Meter Arc
MAI	Metron Aviation, Inc
MIA	Miami International Airport
MIT	Miles-In-Trail
MOD	Modesto Airport
MRY	Monterey Airport
MSP	Minneapolis/St. Paul Airport
NAS	National Air Space
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Control Association
NEXTOR	National Center of Excellence for Aviation Operational Research
NMACS	FAA's Near Mid-Air Collision System
NRP	National Route Program
NTSB	National Transportation and Safety Board
NWS	National Weather Service
OA	Outer Arc
OD	Operational Deviation
OE	Operational Error
ORD	Chicago O'Hare International Airport
PBI	West Palm Beach Airport
pFAST	Passive Final Approach Spacing Tool
POET	Post Operations Evaluation Tool
RDD	Redding Airport
RNO	Reno Airport
RSW	Fort Myers Airport
SCT	Southern California TRACON
SFO	San Francisco International Airport

SMF	Sacramento Airport
SPO	Strategic Plan of Operation
SRQ	Sarasota Aiport
STA	Scheduled Time of Arrival
STAR	Standard Terminal Arrival Route
TBM	Time-Based Metering
TMA	Traffic Management Advisor
TMC	Traffic Management Coordinator
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control Facility
URET	User Request Evaluation Tool
VFR	Visual Flight Rules
ZAU	Chicago ARTCC
ZAU	Chicago Center
ZDC	Washington Center
ZDV	Denver Center
ZFW	Ft. Worth Center
ZID	Indianapolis Center
ZKC	Kansas City Center
ZLA	Los Angeles Center
ZMA	Miami Center
ZME	Memphis Center
ZMP	Minneapolis Center
ZOA	Oakland Center
ZOB	Cleveland Center
ZTL	Atlanta Center